BAKING SCIENCE AND TECHNOLOGY

in Two Volumes

VOLUME II

BAKING SCIENCE AND TECHNOLOGY

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Dedicated to

DR. F. P. SIEBEL, SR.

Forceful leader and inspiring teacher

CONTENTS

Volume II

PART III—BAKING TECHNOLOGY

PART IV—ASPECTS OF CAKE BAKING

PART V—BAKERY EQUIPMENT

BAKING SCIENCE AND TECHNOLOGY

VOLUME II

PART III—BAKING TECHNOLOGY

CHAPTER XV

DOUGH MIXING

The first basic step in the actual production of bread, or, for that matter, of any baked product, is the exact scaling or measuring of the individual ingredients that make up the dough, such as flour, water, yeast, yeast food, milk, malt, sugar, salt, etc., in the amounts required by the specific formula employed. In larger plants the flour and water are usually weighed by means of automatic hopper scales and water metering devices, respectively, while the remaining small ingredients are weighed out individually by smaller scales of high sensitivity.

Dough mixing aims at two principal objectives, namely, (1) the thorough and uniform dispersion of the ingredients to form a homogeneous mixture, i.e., a dough which is alike in all respects throughout every portion of its mass, and (2) to properly develop the gluten into a uniform structure possessing to an optimum degree certain characteristics of pliability, elasticity, hydration, etc. To attain these objectives requires considerable skill and careful control of such mixing factors as absorption, temperature, mixing speed and time.

The ingredients of average white bread include a limited number of essential materials and may include one or several of a multitude of additional adjuncts that find use in bread baking. The following white pan bread formula may be considered as being typical of modern practice.

White Bread Formula

	% on Flour Basis
Flour	100
Water	65 (variable)
Yeast	2
Yeast food	0.25-0.50
Malt	0.5-1.0
Salt	2
Sugar	6
Non-fat dry milk solids	6
Shortening	4

Only those ingredients which are generally considered as contributing to the accepted character of white bread are included, and no effort is made to make allowances for the wide variety of materials, such as potato flour, nonviable yeast, soybean, peanut and cottonseed flour, whey solids, etc.,

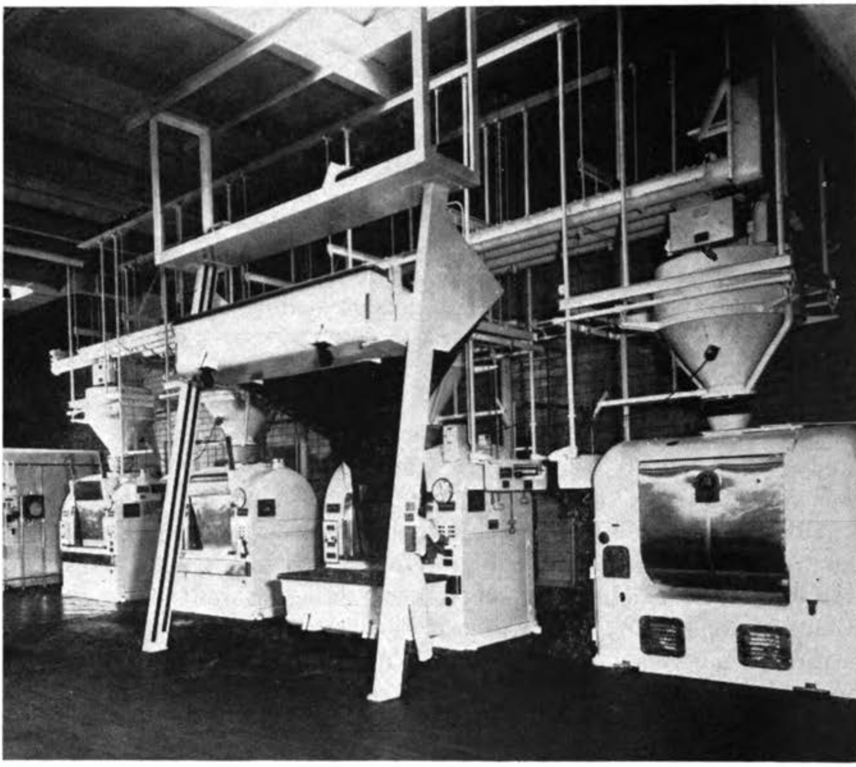


FIG. 59—Mixing department of a modern baking plant. (*Courtesy Burny Bros. Bakeries.*)

etc., which at one time or another find advocates and adherents among bakers.

While this formula is representative, it must be kept in mind that if it is to be adapted to any given shop, certain minor adjustments will be required to make it conform to the special peculiarities inherent in the equipment and baking conditions that distinguish one baking plant from another.

The carefully weighed ingredients are combined in the mixer and mixed to the desired degree. The order in which the various ingredients are added to the mixer can be varied considerably and depends largely upon the preferences of individual operators. When a vertical mixer is used, one recommended procedure is the following: Part of the measured dough water, which has previously been tempered to the correct temperature, is withdrawn for the purpose of suspending the yeast. The balance of the water is then placed in the mixing bowl and the small ingredients, such as the sugar, salt, malt, yeast food, and milk solids, are added and stirred

thoroughly until a uniform suspension or solution is obtained. The machine is then started at low speed and part of the flour, usually about one-half of the total charge, added and mixed into a batter. This requires about one-half minute. The yeast suspension is then added, followed by the remaining portion of the flour. After mixing has proceeded for an additional two to three minutes, the shortening is added last and mixing continued until a smooth elastic dough is obtained. Depending upon the

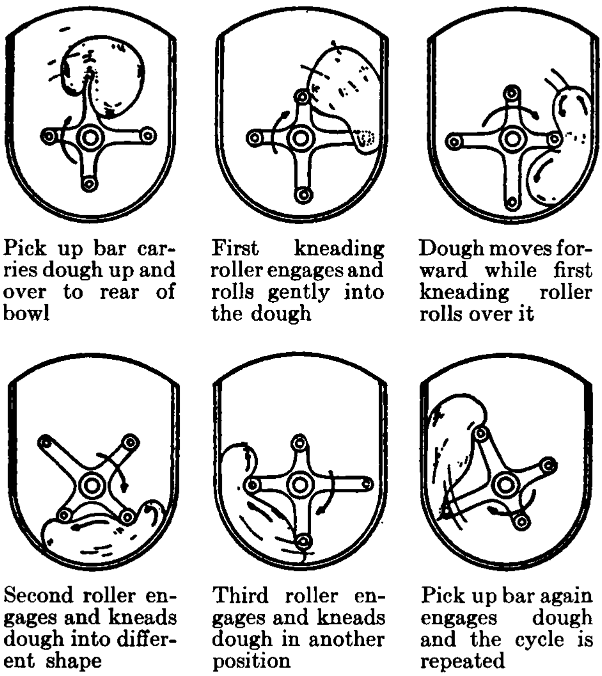


FIG. 60—Sequence drawings of typical dough mixer action. (*Courtesy Food Industries.*)

speeds available with such mixers, this stage is reached in from 8 to 12 minutes.

In the case of high speed horizontal mixers, a frequent practice is to place the dry ingredients, i.e., the flour, salt, sugar, milk solids, malt and yeast food in the bowl, and stir them into a uniform mixture by a few turns of the mixing arms or bars. Then are added the yeast solution, prepared by crumbling and stirring the yeast in a small quantity of water at a temperature of 60 to 70° F., the balance of the dough water, malt syrup and other liquids. After mixing has reached the half way point the shortening is added. This general procedure prevents the excessive splashing that occurs when the liquid ingredients are placed first in the

bowl. Many operators prefer to predissolve the small ingredients, such as the salt, sugar, malt, milk solids, etc., in a special tank in part of the dough water and then add the uniform mixture to the flour in the bowl at one time. Others place the dry milk on top of the flour or sift it in with the flour prior to mixing. By so doing they avoid the possibility of lump formation which is liable to occur when the dry milk solids are placed in direct contact with the ingredient water. The yeast suspension should consist only of the yeast and water, i.e., it should not contain the salt, sugar, malt, or yeast food since these substances, when present in high concentrations, exert a plasmolyzing effect upon the yeast and thereby reduce its fermenting capacity.

The reason for adding the fat or shortening last, or after the dough has begun to form, is that shortening acts as a lubricant by coating the individual gluten strands and particles. If shortening is added at the outset of mixing, gluten development is interfered with by this lubricating effect since the individual gluten strands find it difficult or impossible to adhere to each other with sufficient cohesive force to permit their proper stretching and folding, their lubricated surfaces sliding past each other. On the other hand, the addition of the fat after dough formation has begun introduces the lubricating effect at a time when the gluten structure has already been formed and gluten development is well on its way. It also comes sufficiently early to assure uniform and complete dispersion of the fat throughout the dough mass. This condition is further facilitated by bringing the fat to a soft condition or even melted form prior to its addition to the dough and by the use of certain emulsifying agents.

STRAIGHT DOUGH METHOD

The two commonly used methods of dough mixing are the so-called straight dough method and the sponge dough method. Each has its certain advantages as well as limitations and the selection by a baker of either method depends largely upon individual preferences and the prevailing shop conditions. The straight dough method is a single-step process, such as has been discussed thus far, in which all the ingredients are mixed together into a single batch. Mixing in this case is continued until the dough assumes a smooth appearance and acquires an elastic character. The temperature of the dough out of the mixer should fall within the range of 78° to 82° F. Temperatures beyond that range are undesirable unless the aim is to reduce the fermentation time in which case slightly greater than normal amounts of yeast must be used. The advantages usually associated with the straight dough method are as follows:

(1) Being a one-step process, its labor requirements are at a minimum.

(2) Because the total fermentation time of straight doughs is consider-

ably shorter than that of sponge doughs, the fermentation loss is correspondingly reduced.

(3) The straight dough method is claimed to permit better flavor development in the baked product.

The limitations of the straight dough method arise primarily from the inflexibility of the procedure. Thus it does not permit of cuts or additions and requires a fixed fermentation time. Ripe straight doughs must be taken up when ready, with little leeway in either direction. Little can be done to rectify an over-fermented straight dough in case of schedule disruption and the only practical way of salvaging it is to use it up by adding it in small portions to new doughs as they are being mixed.

SPONGE DOUGH METHOD

The sponge dough method, in contrast to the straight dough method, consists of two distinct steps, the first of which is called the sponge stage, and the second the dough stage. The sponge stage involves the mixing of part of the dough ingredients followed by a preliminary fermentation. In the dough stage the fermented sponge is combined with the balance of the ingredients, mixed, and subjected to a second fermentation of relatively short duration.

The sponge generally incorporates from 50 to 75 percent of the total flour of the complete dough, the total yeast, the yeast nutrients, the malt, and sufficient water to yield a moderately stiff dough. Depending upon the character of the flour, it may also contain part of the milk solids, sugar and shortening, although normally these ingredients are added at the dough stage. Thus if the flour lacks in diastatic activity, the addition of the fermentable carbohydrates will accelerate fermentation. If, on the other hand, the flour possesses an excess of amylolytic activity, the addition at the sponge stage of part or all of the dry milk solids will tend to keep the fermentation at the correct rate. Whether or not all or part of the shortening is added to the sponge depends upon the individual preference of the operator, although the generally accepted practice is to add the shortening at the dough stage. The mixing procedure of the sponge follows that of the straight dough in all essentials, except that the temperature of the mixed sponge should be limited to the range of 72° to 78° F. A great many bakers adhere to the practice of turning out fairly stiff sponges by withholding a few percent of the normal water absorption called for by the flour. The water thus held out is then made up at the dough stage. Stiffer sponges have been found to hold up better, to expand to a greater volume and to yield better gluten development. However, there is also a considerable number of experienced bakers who consistently run slack or soft sponges, obtained usually by over-mixing,

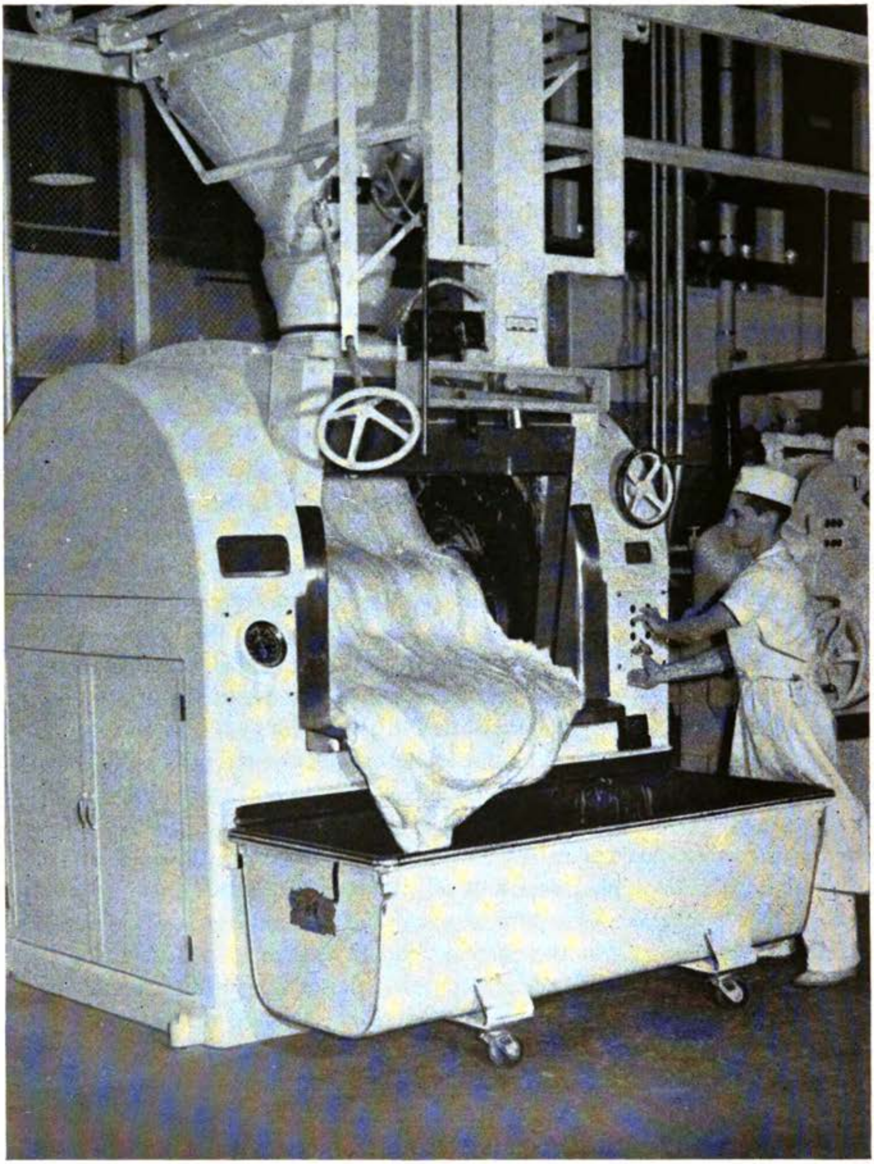


FIG. 61—Sponge being discharged from horizontal mixer into dough trough.

with excellent results. As in so many phases of the baking process, experience and a thorough understanding of the existing peculiar shop conditions must to a large degree govern the manner in which sponge mixing is carried out.

After the sponge has been mixed, it is set to ferment until it has reached the proper degree of maturity or ripeness which is indicated by a marked recession of the sponge volume, usually called the drop or break. This may require a fermentation time of about 3.5 hours in the case of a sponge incorporating 75 percent of the total flour and a fermentation time of about 5 hours in a sponge made up of 50 percent of the total flour.

The second step of the sponge method is the so-called dough stage in which the fermented sponge is returned to the mixer and the so-called doughing ingredients are added. These comprise the balance of the materials required by the formula and include the remaining flour and water, and the milk solids, salt, sugar, shortening and any additional ingredients called for by the formula. The general mixing procedure is to add the dry ingredients to the sponge and start the mixer so as to cause the mixing arms to break up the sponge. The liquid ingredients are then added and, at about the half-way mark, the shortening is incorporated. The reverse of this procedure, where the sponge is first broken up with the liquid portion of the doughing ingredients, is also used extensively. The dough is mixed to its optimum condition and then returned to the fermentation room where it is fermented for a period ranging from 15 minutes to about an hour. Because the sponge portion of the dough is subjected to double mixing, once in the sponge stage and then again in the dough stage, and also to a considerably longer fermentation, it is generally desirable to use stronger flours in making the sponge and weaker flours for the dough stage.

The advantages of the sponge dough method may be summarized as follows:

(1) There is a saving of approximately 20% in the amount of yeast used as compared with the amount required for a straight dough.

(2) Bread produced by the sponge dough method tends to have greater volume and a more desirable texture and grain.

(3) The method possesses greater flexibility. Sponges can be held longer without marked deterioration of the final product, in contrast to straight doughs which must be taken up when ready.

The most serious disadvantage of the method is the extra labor cost involved in having to subject the dough to two mixings. There are also the additional costs arising from increased power consumption, greater wear of the mixing equipment, and higher fermentation and evaporative losses.

VARIANTS OF MIXING METHODS

While the procedures for the straight dough and the sponge dough methods described above conform to general practice, many variations

and modifications of both methods have been developed by individual bakers. One of the more widely used modifications of the straight dough method is the so-called "remixed straight dough." In this method a straight dough is mixed in the accepted manner except that approximately 8 percent of the dough water is withheld. The mixing time is similar to that of a sponge. The temperature is maintained between 78° and 82° F., the fermentation time 2 to 2½ hours under normal conditions, and 2 to 2.5 percent yeast and 0.5 percent yeast food are used (*1*). After proper fermentation the dough is returned to the mixer without punching or folding and the balance of the dough water added. The dough is then mixed until smooth and given an additional fermentation or floor time of 15 to 30 minutes. These remixed straight doughs require an additional pan proof to bring them to about ½ inch above the top of the pan. The advantages of this method include a better machineability of the doughs which is comparable to that obtained with sponge doughs but in a shorter time, a more uniform baked loaf, and superior eating qualities with markedly improved flavor and taste.

The so-called "no punch dough method" subjects the dough to intensive mixing development, mixing being conducted for a period of from 12 to 18 minutes in a high speed mixer of 65 rpm., the actual mixing time depending upon the mixing tolerance of the flour used. For the production of Pullman bread having desirable flavor, soft texture and tender crust, a low protein short patent flour or a good quality standard grade flour of from 11.5 to 11.8 percent protein content and a 0.42 to 0.43 percent ash content, is recommended. The formula and method suggested for this particular type of bread are as follows (*2*):

Formula for No Punch Dough

	% on flour basis
Flour	100
Water	62
Yeast	2
Yeast food	0.375
Malt	1
Salt	2
Sugar	5
Milk	4
Shortening	4

Dough temperature: 78° F.
Mixing: 12 min. at 65 rpm.
Give full rise, approximately 3 hrs. 30 min. and take to divider without punching.

In the so-called 100 percent sponge method, all the flour, most of the water, and all of the yeast, yeast food, malt and shortening are added at

the sponge stage. After a fermentation of about 3 hrs. and 25 min., the remaining water, the salt, sugar and milk are added and the dough subjected to vigorous mixing. This method is recommended for the production of round top bread possessing superior flavor and tenderness. A general formula for the 100 percent sponge method is the following (*2*):

FORMULA FOR 100% SPONGE METHOD

	% on flour basis	
	Sponge	Dough
Flour	100	
Water	52	12
Yeast	2	
Yeast food	0.375	
Malt	1	
Shortening	4	
Salt		2
Sugar		5
Milk		4

Sponge temperature: 77° F.	Dough temperature: 80° F.
Fermentation: 3 hrs. 25 min.	Floor time: 20 min.
Mixing: 3 min. at 65 rpm.	Mixing: 2 min. at low speed. 12 min. at 65 rpm.

Total time: 4 hrs.

In modern bakery practice it has been found that bread with the best loaf characteristics is obtained with slightly young doughs. The dough resulting from the 100 percent sponge method will be slightly on the young side, having a total fermentation time of only 4 hours. It has a relatively high proofing rate, requiring about 10 minutes less to attain full final proof than does a dough obtained by the fractional sponge dough process. This type of bread requires a fairly moist baking atmosphere to ensure good oven spring.

DOUGH DEVELOPMENT DURING MIXING

Mixing to the correct degree is of the utmost importance from the standpoints of the subsequent handling of the dough as it passes through the make-up stage as well as of the ultimate quality of the finished product. Mistakes committed at the mixer are difficult, and in many cases impossible, to correct during the following stages of production. Insufficiently mixed doughs present a lumpy, sticky character that results from uneven dispersion of ingredients and inadequate gluten development. Such under-mixed doughs yield bread which shows caved-in sides, low volume, streaky crumb and coarse grain. An over-mixed dough exhibits a sticky and runny character which makes it difficult to handle during the sub-

sequent make-up and will also yield bread that shows essentially the same faults as are found with bread from under-mixed doughs.

Clark (*3*), in an excellent discussion, points out that during the mixing process the dough undergoes three distinct phases of development, each clearly differentiated from the other, which may serve as "guide posts" to proper mixing. During the first phase, which extends from the start

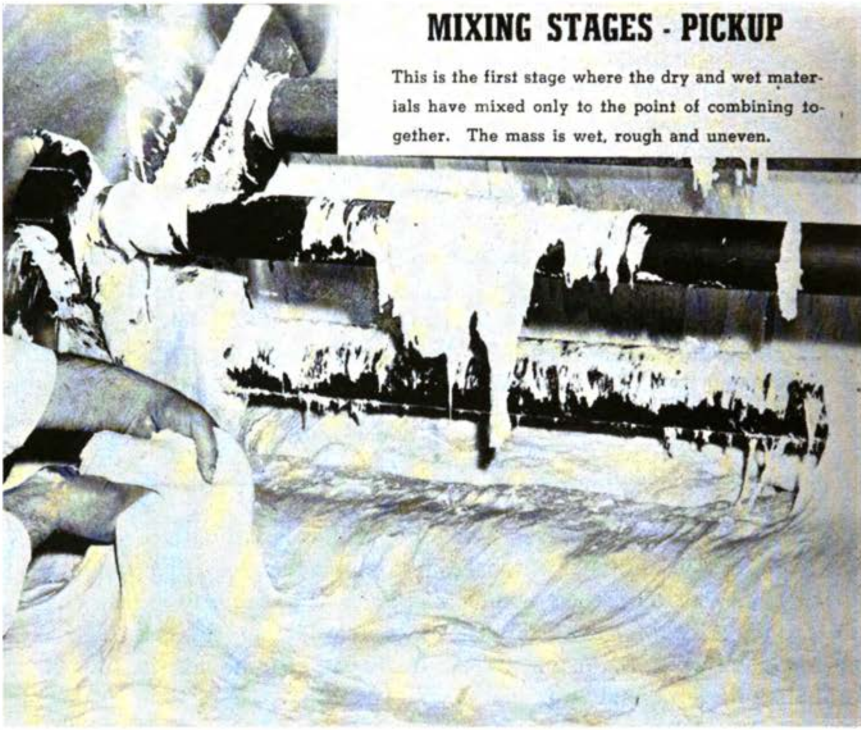


FIG. 62—Dough at the initial or pickup stage of mixing. (*Courtesy Amer. Soc. of Bakery Engineers.*)

of mixing until the so-called clean-up stage, the principal function of mixing consists of thoroughly incorporating the various ingredients into a homogeneous mass. That is to say, that during this phase the starch and protein of the flour are thoroughly wetted by the dough water or liquid milk; the soluble ingredients, such as salt, sugar, yeast food, as well as the soluble flour constituents, are brought into solution in the liquid phase of the dough system, which also serves as the vehicle for the uniform distribution of the yeast throughout the dough. The dough, at this stage, exhibits a completely under-mixed character. There is little so-called development, the dough consisting of large wet pieces possessing

little coherence or elasticity. As mixing is continued, the dough gradually begins to cohere to form a continuous mass, to develop elastic properties, to pull away from the mixer wall, until a point is reached when it leaves the entire mixer bowl clean. This is the so-called "clean up" stage. The appearance of this very definite physical condition in the dough marks the end of the first mixing phase and also constitutes the point by which

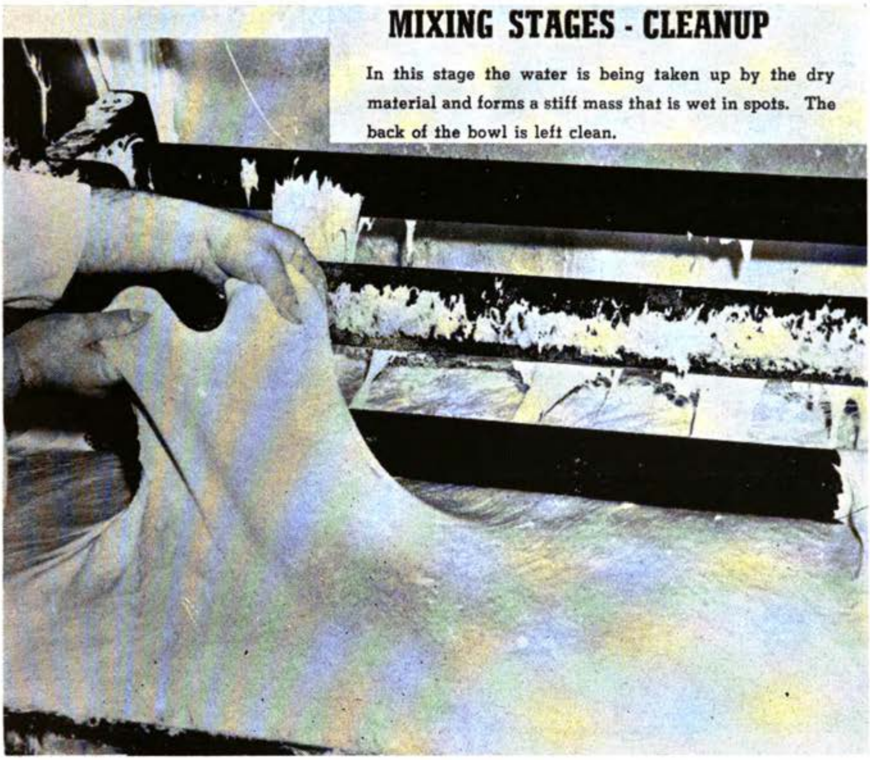


FIG. 63—Dough at the cleanup stage of mixing. (*Courtesy Amer. Soc. of Bakery Engineers.*)

the total mixing time may be gauged. With some flours the dough should be dumped when it reaches this stage. Other flours require mixing beyond it.

The period required for a dough to reach the clean-up stage varies with different flours. Some attain the clean-up stage very rapidly, while others need relatively long mixing. Hence it is improper to set a standard mixing time for a mixer and subject all flours to equal mixing treatment. Clark (*3*) contends that the decisive point is the "clean-up" stage and that all mixing operations should be governed by that point since it rep-

resents "an equilibrium between all the forces of absorption, ingredients, mixing speed, temperatures and flour quality. All such forces contending for supremacy up to this point are balanced." Differences in temperature, absorption, flour, etc., all affect initial dough development. Thus slack doughs require longer mixing than stiff doughs before reaching the clean-up stage. In the case of strong flours, i.e., flours requiring mixing

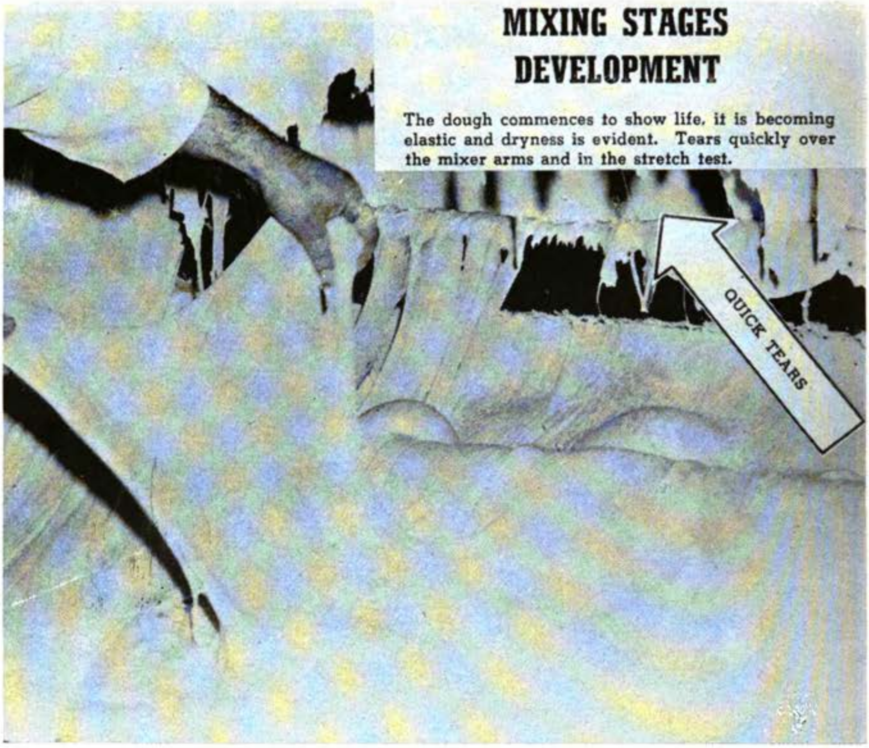


FIG. 64—Dough at the development stage of mixing. (*Courtesy Amer. Soc. of Bakery Engineers.*)

beyond the clean-up stage, subsequent mixing treatment is gauged by this point rather than by the total mixing time elapsed.

The extent of mixing to which the dough is subjected is governed by a number of factors, including flour strength, dough temperature, ingredients, speed of mixing, and the amount of mechanical punishment following the mixing. Low protein, weak flours will generally require dumping just before the clean-up stage is reached, unless subsequent dough handling involes little mechanical punishment, such as in a hand shop. Stronger flours generally must be carried beyond the clean-up stage. The problem, in most instances, is to determine how far additional mixing

should be carried. In this second phase of mixing, the dough becomes smooth, dry, elastic and stiff. It has reached its peak of adherence and toughness. For many of the stronger flours this represents optimum mixing development. Just when to dump the dough during this second phase is best determined by running trial doughs, dumping one dough at the clean-up, the second two minutes after clean-up, and the third four

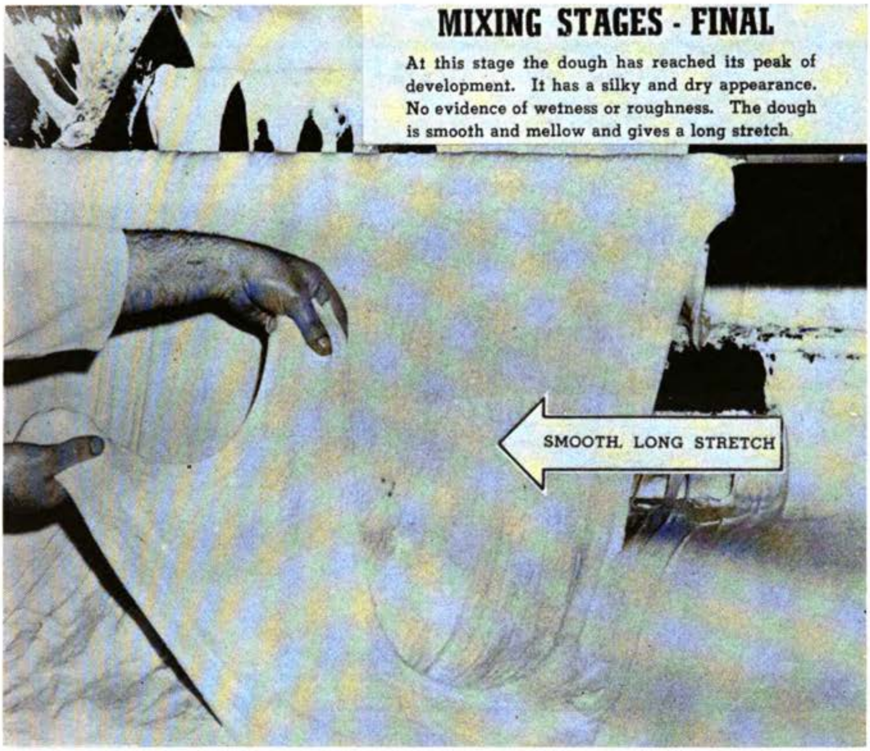


FIG. 65—Dough at the final or optimum stage of mixing. (*Courtesy Amer. Soc. of Bakery Engineers.*)

minutes after clean-up, etc. By comparing the performance of the doughs during the subsequent stages of baking and also the finished products, the optimum mixing time for the given flour is readily determined. As a rule, changing the mixing time by such relatively small time increments prevents undue damage to the dough so that saleable bread is obtained with all trial doughs.

As mixing is continued through this second phase, the dough loses its stiff elastic character and becomes soft, smooth and highly extensible, and assumes a silky appearance. Its massive coherence diminishes and the dough begins to be pulled into long, rubbery strands by the mixer bars.

This is the so-called "let-down" stage and marks the end of the second phase and the beginning of the third. Very few exceptionally strong flours may be safely carried to this stage since a very real danger exists that such an over-treated dough will be unable to stand up under the subsequent mechanical punishment imparted to it during fermentation, dividing, rounding, moulding and proofing without a complete breakdown of its cell structure.

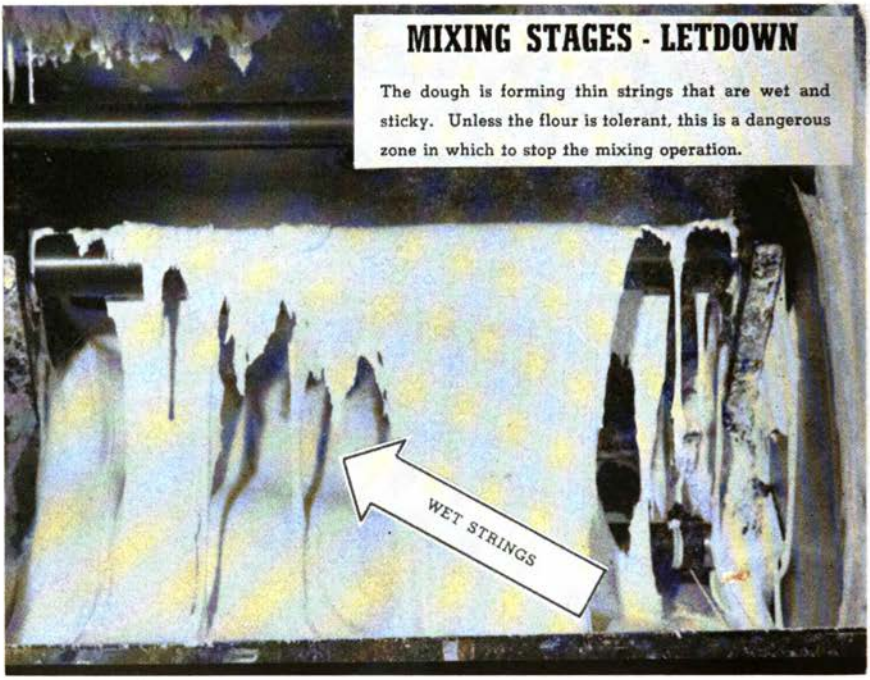


FIG. 66—Dough at the letdown stage of mixing. (*Courtesy Amer. Soc. of Bakery Engineering.*)

Doughs mixed beyond the "let-down" stage disintegrate completely. They become slack and runny, losing all their elasticity. No gluten can be washed from doughs mixed into this phase. It is rare indeed that doughs are ever purposely carried into this phase, since the chances of satisfactory subsequent recovery are negligible, except with very unusual flours.

The physical changes that characterize the individual mixing stages were also described more recently by Swortfiguer (*4*). Figures 62-67, taken from the data by Swortfiguer, show in a visual manner the progressive development of a dough as it passes from the pickup stage on through the clean-up, development, final letdown and breakdown stages.

The factors involved in the loss of coherence and in the increase in mobility of doughs upon prolonged mixing have been reviewed by Markley and Bailey (*5*). Among the causes leading to increased mobility mentioned by these authors are proteolytic activity, the liquefying action of alpha-amylase upon the starch of the dough, the mechanical damage to the gluten structure, the chemical effects of cysteine and glutathione.

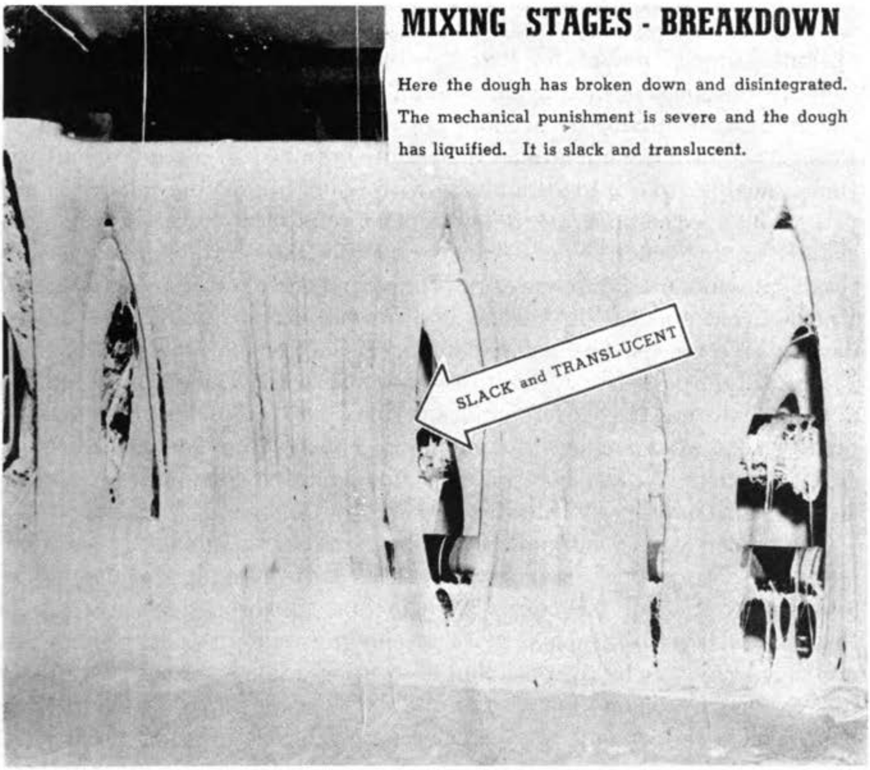


FIG. 67—Dough at the breakdown stage of mixing. (*Courtesy Amer. Soc. of Bakery Engineers.*)

Ions such as bromate, chloride, calcium, magnesium, sulfate or carbonate in small quantities have been found to reduce the rate of mobility increase. Additional factors which influence the rate of mobility increase are the hydrogen ion concentration, the presence of milk solids, and even the manner in which the wheat was conditioned for milling.

The relationship of mixing speed to dough development and bread characteristics was investigated by Stamberg and Bailey (*6*). They found that the optimum mixing time was longer for a strong flour than for a medium strong flour. Doughs to which 6 percent dry milk solids

had been added required longer mixing times than milk-free doughs so that the effect of milk solids was to increase the strength of flour. In general, bread scores from doughs mixed at the medium speeds of 60 to 80 revolutions per minute were higher than the bread scores of either slower mixed or more rapidly mixed doughs. A further advantage of medium speed mixing is that the range of time through which mixing can be continued for optimum results is much greater than with higher speeds. Low speed mixing in general gave the poorest results even when the optimum time of mixing for that speed was allowed.

While the speed of mixing has a definite effect upon dough development, the duration of mixing is far more important, as has been stressed above. Pelshenke (7) has summarized the results obtained in a study of mixing times ranging from 2 to 10 minutes with flours of varying qualities, and using a high speed mixer, as follows: (1) Flours react markedly to variations in mixing times. Slight reductions or increases in the mixing periods result in pronounced differences in volume and grain of the baked product. Under-mixed doughs yield dense and uneven crumbs, while over-mixed doughs give uneven grain and a reduced elasticity of the crumb. (2) Fermentation periods are significantly influenced by mixing, over-mixed doughs requiring longer fermentation times. (3) Differences in baking quality that exist among different flours can be completely masked by faulty mixing. Weak flours properly mixed may yield superior results to strong flours improperly mixed.

The tendency with mechanized baking is to operate at slightly less than optimum absorptions to avoid difficulties with sticking doughs in the make-up equipment. Frequently reductions in absorptions are greater than is warranted, resulting in corresponding reductions in yield. The aim should always be the optimum absorption a flour will carry, not only for reasons of economy but also of quality. Garnatz (*8*) has reported on baking tests performed under commercial conditions in which the normal absorption of flour was increased by 4 percent. He arrived at the following conclusions:

1. The mixing time is increased with the increased absorption.
2. The weight of dough obtained is increased by an amount which corresponds roughly to the weight of the extra water added.
3. The loss in weight from divider to slicer, which is greatly affected by oven conditions, generally increases progressively with absorption, though this need not necessarily be so.
4. Extra bread yield is obtained.
5. Provided good control exists throughout the process and especially at the oven, increased absorption is recoverable as bread almost pound for pound.

6. The efficiency of converting "dry matter" to bread is raised.
7. Bread with increased moisture is obtained.

When increasing absorption above normal, the following precautions should be taken:

1. The accuracy of scaling flour and other ingredients into the mixer should be closely watched and checked at regular intervals.
2. Excessive shrinkage and mechanical loss of dough in the dough room should be avoided.
3. The efficiency of the divider operation with respect to scaling weight must be closely watched.
4. The highest absorption consistent with proper working qualities in the dough is of prime importance and contributes to maximum bread yield and, incidentally, bread quality.
5. Close study of the proper oven conditions adequate for properly baking bread and subsequent control thereof will result in a minimum bake-out and a maximum yield of bread.

The following table reproduces one set of data found by Garnatz which can be considered as representative of the general results obtained.

TABLE 103. EFFECT OF CHANGES IN ABSORPTION

	Test I			Test II		
% Absorption	62	66	70	62	66	70
Mixing time (min.)	7	9	13	5.5	8	10
Extra water added (lbs)	—	27	52	—	27	52
Extra dough obtained (lbs.)	—	24	52	—	33	69
% Loss, divider to slicer	12.1	12.1	11.6	13.5	11.87	12.38
Extra lbs. of bread obtained	—	29.4	55.2	—	47.7	73.3
% Extra dough recovered as bread		101.4	106.1	—	144.6	106.2
% Conversion of "dry matter" at 38% moisture	92.0	94.3	96.7	89.8	94.2	96.5
Actual moisture content of bread	35.4	36.1	37.5	35.6	35.7	37.2

REFRIGERATION APPLIED TO MIXING

Dough mixing is accompanied by a noticeable rise in the temperature of the dough mass. The two principal sources of heat generation are the heat evolved during the hydration of the flour by the dough water and the heat produced by the frictional forces operating during mixing. This friction heat is actually supplied by the mixer motor and its quantity is therefore dependent upon the horsepower rating of the motor and the mixing time. As a general rule, the heat generated by the mixer motor amounts to ap-

proximately 42.4 B.T.U.'s (British Thermal Units) per motor horsepower per minute of mixing time. A B.T.U. is the amount of heat required to increase the temperature of 1 pound of water by 1° F.

The heat generated during dough mixing must be removed by one means or another in order to have the dough leave the mixer at a temperature of 78° to 80° F. Reduction in temperature is generally obtained by one of three methods: (1) use of crushed ice; (2) use of cooled ingredient water; and (3) application of refrigeration to the mixer bowl. Earlier attempts to obtain adequate cooling by the introduction of chilled air into the mixer have been abandoned as unsatisfactory so that the three procedures mentioned represent the only practicable methods of dough cooling.

The use of crushed bulk ice is largely limited to smaller bakeries lacking mechanical refrigeration of any kind. Since the ice represents part of the ingredient water and since it is essential that uniform liquid distribution throughout the dough be attained during the mixing period, it is obvious that the ice must be added in a finely crushed form to facilitate rapid melting. Larger pieces of ice may not melt completely during the mixing operation, causing the occurrence of water pockets in the fermenting dough with subsequent irregular fermentation. Because of the difficulties and inconveniences involved in the storing, handling, weighing and crushing of bulk ice, its use as a cooling medium in the bakery is slowly diminishing. On the other hand, the development of new, highly compact ice making machines that may be located at any desired space within the plant has gone far in rendering the use of ice for dough cooling more convenient. Some units, requiring only 6 square feet of floor area, will produce as much as one ton of ice in 24 hours. The ice is usually supplied in the form of moist snow or very fine flakes which melt rapidly and are therefore particularly suited for dough cooling purposes. One unit, described by Winther (*9*), produces thin ice flakes by rotating a refrigerated stainless steel drum partially submerged in a water bath. Ice forms on the surface of the drum to a thickness of about 0.1 inch and is scraped off by a special cutter wheel at the uppermost point of the drum where it emerges from the water bath. The finely and uniformly flaked ice is dropped from the unit by means of a chute. However, even with the use of such ice machines there still remains the need for calculating the ice requirements with changing ingredient and water temperatures. This is both cumbersome and subject to error. Hence the trend is toward the use of refrigerated ingredient water and, where that is inadequate, also toward refrigeration of the mixing bowl.

Various types of water cooling units are available which deliver large quantities of water chilled to a temperature of 35° to 40° F. The use of cold ingredient water is highly efficient provided that sufficient quantities

of such water can be used to absorb the total heat load of the dough. This is usually the case with straight doughs and the majority of sponges. In sponge doughs, however, the amount of water added at the re-mix stage is frequently found to be insufficient to provide adequate temperature control. In such cases the normal practice is to apply supplementary refrigeration to the mixing bowl.

FIG. 68—Compact cooling unit of self-contained design which provides chilled ingredient water and refrigeration for mixer jacket cooling. (*Courtesy Read Standard Corp.*)

There are two basic systems of jacket cooling—the indirect system in which a cooling medium is circulated through the mixer bowl jacket, and the direct system in which the refrigerant itself is introduced into the jacket and produces its cooling effect by its rapid evaporation. In both instances the mixer bowl must be provided with a properly designed jacket, or double wall construction, to allow free circulation or expansion of the cooling medium in the space enclosed between the jacket walls. Design

requirements differ, of course, with the type of refrigeration applied and the baker is usually able with most standard mixers to specify the type of cooling system he prefers.

The calculation of the cooling load required to produce a dough at the desired temperature is of obvious importance as a control measure. The procedures by which ice and mechanical refrigeration requirements may be determined under given temperature and mixing conditions have been described by many authors, the most recent references to this subject being those of Eckstedt (*10*) and Stribling (*11*).

CONTROLLING DOUGH TEMPERATURE WITH ICE

To determine the amount of ice to be used in sponge mixing, we must know the temperature of the flour, the temperature of the mixing room atmosphere, the temperature increase produced by the heat evolved during mixing as a result of both friction and flour hydration, and the temperature of the available ingredient water. The temperatures of the flour, room and water are readily obtained by thermometer readings. The friction heat of the mixer must be determined experimentally by mixing a test dough and measuring the increase in dough temperature obtained. In carrying out this test the temperatures of the room, flour and water should be noted. The calculation itself is made by multiplying the dough temperature obtained by 3 (since 3 factors are involved, namely, flour, water, and room temperatures) and subtracting from the sum of this multiplication the sum obtained by adding the temperatures of the three factors obtained. Assuming a final dough temperature of 82° F, a flour temperature of 70° F., a water temperature of 60° F. and a room temperature of 80° F., the calculation will yield the following result:

Final dough temperature	82° F.	
then 82° F. × 3		246° F.
Flour temperature	70° F.	
Water temperature	60° F.	
Room temperature	80° F.	
Total of 3 factors	210° F.	210° F.
Mixer friction heat		36° F.

It has been stated above that the temperature increase brought about by mixing, and designated here as "mixer friction heat," includes also the heat of hydration. Hence the mixer friction heat obtained will hold true only in cases where the moisture content of the flour used is the same. As will be shown subsequently, the heat of hydration of flour varies with the flour's moisture content, being greater the lower the moisture content. Hence, unless the moisture content of flour is closely controlled by means

of proper storage conditions, the mixer friction heat obtained will only be a close approximation of the actual heat load imposed upon the dough by the mixer. Under normal conditions this variability is usually negligible and may be ignored, although pronounced changes in relative humidity conditions may require some adjustments. The duration of mixing also is an important factor and if mixing periods are varied it is necessary to re-establish the mixer factor for each time variation.

Now let us assume that a final dough temperature of 78° F. is desired. To determine the water temperature required to obtain this temperature, the following procedure of calculation is employed:

Dough temperature desired...	78° F.	
then 78° × 3............		234° F.
Mixer factor...............	36°	
Flour temperature..........	70°	
Room temperature..........	80°	
	186°	186°
Temp. of water required.....		48° F.

It has been assumed that the available tap water has a temperature of 60° F. The problem therefore is—how much ice must be used to reduce the temperature of any amount of water from 60° F. to 48° F.? For the sake of example, let us say that 300 lbs. of dough water are required. To melt 1 lb. of ice to water requires the application of 144 B.T.U.'s, or in other words, when 1 lb. of ice is melted, a heat equivalent of 144 B.T.U.'s is withdrawn from the environment, in this instance the dough mass. It has been indicated earlier that one B.T.U. represents the amount of heat required to raise the temperature of 1 lb. of water by 1° F., so that, conversely, to reduce the temperature of 1 lb. of water by 1° F. requires the removal of 1 B.T.U. Hence to reduce 300 lbs. of water from 60° F. to 48° F., or by 12°, requires the withdrawal of 300 × 12 or 3,600 B.T.U.'s. Dividing the latter sum by 144 yields 25 which is the amount of ice in pounds needed. This amount of ice must be deducted from the total dough water so that under the assumed conditions 275 lbs. of water at 60° F. and 25 lbs. of ice will produce a dough with a temperature of 78° F. Summarized numerically, the calculation assumes the following form:

$$\begin{aligned} 60^\circ\text{ F.} - 48^\circ\text{ F.} &= 12^\circ\text{ F.} \\ \therefore\ 300 \times 12^\circ &= 3{,}600^\circ \\ 3{,}600 \div 144 &= 25\text{ lbs. of ice} \end{aligned}$$

In calculating the cooling requirements of a sponge dough, the temperature of the returning sponge becomes an additional factor which must be added to the temperature of the flour, room, and mixer factor. Assuming

that the returned sponge has a temperature of 84° F. and that a final dough temperature of 80° F. is aimed at, the calculation assumes the following form:

Dough temperature desired...	80° F.	
then 80° × 4............		320°
Mixer factor...............	36°	
Flour temperature..........	70°	
Room temperature..........	80°	
Sponge temperature.........	84°	
	270°	270°
Temp. of water required.....		50°

The amount of ice needed to reduce the temperature of a given amount of water from 60° F. to 50° F. is then calculated by the procedure outlined above.

DETERMINING REQUIRED REFRIGERATION CAPACITY

Where mechanical refrigeration is either available or being planned, the capacity of the refrigeration machine needed for a given production volume may also be calculated quite accurately. It has been pointed out above that the heat load involved in dough mixing includes (1) the sensible heat of ingredients, (2) the heat of hydration of flour, (3) the heat put in by the mixer motor (which corresponds to friction heat). To these may be added as a fourth and usually negligible factor the heat absorbed by the mixer jacket from the environment. In order to properly calculate in terms of B.T.U.'s the amount of heat contributed by each of these sources, certain constant factors must be known and employed. These include the sensible heat of ingredients which is readily measured by means of a thermometer, the specific heats of flour, dough and water, the heat of hydration of flour at different moisture contents, the heat generated by the mixer motor, etc. The generally used values for these factors are as follows:

Specific heat of flour..............	0.42	B.T.U.	
Specific heat of dough..............	0.60	"	
Specific heat of water..............	1.00	"	
Average heat of hydration of flour...	6.5	"	
Heat generated by mixer motor.....	42.4	"	per min./HP
Heat absorbed by mixer jacket......	usually negligible		
Sensible heat of small ingredients....	usually negligible		

Since the refrigeration capacity must be adequate for the maximum loads encountered and since these occur during the dough mixing stage of

the sponge dough method, the following example of calculation is based on an approximate 1050 lb. sponge dough consisting of:

600 lbs. of sponge
250 lbs. of dough flour
150 lbs. of dough water
50 lbs. of small ingredients

1,050 lbs. total dough weight

It is also based on the following assumptions: the mixing schedule requires 3 mixes per hour with a mixing time of 10 minutes per dough, and a final dough temperature of 78° F.; the flour enters the mixer at 90° F. and has an average moisture content corresponding to a heat of hydration of 5.6 B.T.U.'s per pound; ingredient water is chilled to 40° F. and the sponge is returned at 83° F.; the average effective mixer horsepower is 25 HP. The capacity of a direct expansion jacket cooler required under these conditions may be calculated as follows:

To cool the sponge from 83° F. to 78° F., a difference of 5° F., requires the withdrawal of B.T.U.'s equivalent to the sum of the weight of the sponge multiplied by the specific heat of dough multiplied by the temperature difference between 83° and 78°, or $600 \times 0.6 \times 5 = 1800$ B.T.U.

The cooling requirement to reduce the flour from 90° F. to 78° F. is calculated by the same procedure, namely, by multiplying the weight of the flour by its specific heat and by the temperature difference, or $250 \times 0.42 \times 12 = 1260$ B.T.U.

To remove the heat of hydration of the flour requires the withdrawal of B.T.U.'s equivalent to the sum obtained by multiplying the weight of the flour by the hydration factor, or $250 \times 6.5 = 1625$ B.T.U.

The cooling of the 50 pounds of small ingredients, part of which reach the dough at 78° F. or lower, is such a minor item that it may be ignored in the overall calculation.

The heat load generated by the 25 HP mixer motor running 10 minutes during each mix is equal to the mixer factor per horsepower per minute multiplied by 10 (for the 10 minute mixing period), or $42.4 \times 25 \times 10 = 10600$ B.T.U.

The heat absorbed by a well-insulated mixer jacket from the environment is usually too small to enter significantly into the calculation.

The chilled ingredient water at 40° F. has a cooling effect and on being warmed to 78° F. during mixing, will withdraw B.T.U.'s from the rest of the dough mass. The amount of this cooling effect is equal to the weight of the water multiplied by its specific heat multiplied by the temperature difference between 40° F. and 78° F., or $150 \times 1 \times 38 = 5700$ B.T.U. withdrawn.

Summarizing the heat load of a 1050 lb. dough under the assumed conditions, the following tabulation results:

Source of Heat	Amount of Heat
Sponge	1,800 B.T.U.
Flour	1,260 "
Heat of hydration	1,625 "
Mixer motor	10,600 "
Small ingredients	negligible
Jacket conduction	negligible
Total heat input	15,285 B.T.U.
Chilled ingredient water	−5,700 "
Machine capacity required	9,585 B.T.U.

Thus the refrigeration machine must absorb a heat load of 9585 B.T.U. in 10 minutes of mixing time or at a rate of 958 B.T.U. per minute. Since refrigeration units are rates on an hourly capacity, a machine capable of absorbing 958 × 60, or 57480 B.T.U. per hour is required for the above heat loads. Such a performance is obtained from a unit of approximately 10 HP.

In determining the capacity of an indirect jacket cooling system, the heat loads are calculated as above. The actual capacity of the refrigeration unit is obtained by considering several additional factors. Let it be assumed that a water cooler is available with sufficient storage capacity to permit the refrigeration machine to operate 20 minutes for each mix, that a circulating pump is driven by a 0.5 HP motor, and that the water system has a total conduction loss of 1000 B.T.U. per hour. Then:

(1) The jacket cooling load per hour will be: 3 × 9585 B.T.U. per mix = 28755 B.T.U.
(2) The heat input from the pump will be: 0.5 × 42.4 × 60 = 1272 B.T.U. per hour.
(3) The conduction loss has been assumed to be 1000 B.T.U. per hour.

This gives a total cooling load of 31028 B.T.U. per hour. This capacity is obtained with a 5 HP machine which will deliver cooling water at 40° F. with an intake of return water at 45° F. Since the refrigeration machine runs for 20 minutes, or twice the length of the mixing period, to remove 9585 B.T.U. per mix from the cooling water, it is obvious that only one half, or 4793 B.T.U. will need to be removed by the refrigeration machine during the actual mixing time of 10 minutes. The remaining 4793 B.T.U. must be absorbed by the stored cooling water with a resultant maximum temperature rise of 5° F., i.e., from 40° F. to 45° F. The storage capacity of the cooler must therefore be:

$$\frac{4793}{1 \times 5^\circ \times 8.3 \text{ lbs./gallon}} = 115 \text{ gallons}$$

Hence a 5 HP refrigeration machine and a water cooler with an approximate storage capacity of 120 gallons will prove adequate to take care of the cooling requirements under the above indicated conditions. The reason why the indirect cooling system requires only about one half the refrigeration capacity of the direct cooling system lies in the fact that the refrigeration machine is in operation for about twice the time period in the former case as compared with the latter. Thus in direct cooling, the refrigeration unit operates intermittently and its capacity must be fully exerted within the actual mixing period which in the above case was 30 minutes out of the hour. In indirect cooling, on the other hand, the cooling medium, whether water or brine, stores approximately one half of the total cooling requirement in the interval between mixes during which the refrigeration unit is kept operating continuously. Hence, for three doughs per hour with each dough requiring 10 minutes of mixing, the machine is run the full hour since it requires 20 minutes for the unit to provide adequate refrigeration for each batch.

The cooling loads of both sponges and straight doughs are considerably less as compared with a sponge dough, assuming that chilled ingredient water is available. In the case of sponges this is due to the generally shorter mixing time used which results in a correspondingly reduced heat input by the mixer motor, and the relatively higher proportion of chilled ingredient water which cancels out much of the normal heat load. In the case of straight doughs, the heat load of the sponge is eliminated and the relative proportion of chilled ingredient water to total dough mass is more favorable from a heat balance standpoint. Thus, assuming the general conditions outlined above, in a 1000 lb. straight dough the flour would contribute approximately 6400 B.T.U. as sensible heat and as heat of hydration, and the motor heat input would be about 10600 B.T.U., making a total of some 17000 B.T.U. The ingredient water chilled to 40° F. would remove from the dough mass some 13000 B.T.U., leaving a balance of 4000 B.T.U. per dough to be removed by mechanical refrigeration.

HEAT OF HYDRATION

It has been seen that the heat of hydration of flour contributes a significant addition to the mixer cooling requirements. Heat of hydration may be defined as the amount of heat evolved by a substance when it takes up water. The theoretical explanation is that the energy which keeps the water molecules in motion is liberated when that motion is arrested by the adsorptive forces of the substance taking up the water. The amount of heat liberated varies with the degree to which water is adsorbed, which in turn depends upon the nature of the adsorbing ma-

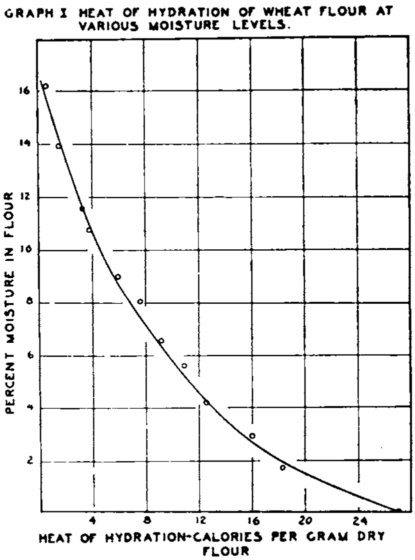


FIG. 69—Heat of hydration of wheat flour at various moisture levels.

terial. A completely dry substance will evolve the greatest amount of heat on hydration because a greater proportion of water molecules will be firmly bound to its surfaces. As the moisture content of the substance increases, less and less heat is liberated. Hence it is evident that in substances such as flour the initial moisture content will have a marked influence on the heat of hydration. This effect has been studied by several investigators. Grewe (*12*) observed that flours with moisture contents of 13.1 and 8.7 percent produced finished doughs whose temperature differed by 33° C. (5.9° F.). Similar observations were made by Winkler and Geddes (*13*), and Schrenk, Andrews and King (*14*). Lincoln, Dirks and Harrel (*15*) have tabulated the relationship between moisture content and amount of heat of hydration for wheat flour. The following table is adapted from their data.

TABLE 104. B.T.U. HEAT EVOLVED, INCREASE IN DOUGH TEMPERATURE AND THE AMOUNT OF ICE REQUIRED TO COMPENSATE FOR THE HEAT OF HYDRATION OF 600 LBS. OF FLOUR (14% MOISTURE BASIS) AT VARIOUS MOISTURE LEVELS

Moisture content of flour %	Heat of hydration BTU per lb. (moisture-free basis)	BTU given off by 600 lbs. of flour (14% moisture basis) due to heat of hydr.	Calculated increase in dough temp. due to heat of hydration (without refrigeration)		Pounds of ice required to compensate
%	B.T.U.	B.T.U.	° C	° F	Lbs.
14.0	2.67	1,602	1.1	2.0	7.3
13.0	3.75	2,250	1.6	2.9	10.2
12.0	4.82	2,892	2.0	3.7	13.1
11.0	6.25	3,750	2.6	4.8	16.9
10.0	7.85	4,710	3.3	6.0	21.3
9.0	9.64	5,784	4.1	7.4	26.1
8.0	11.92	7,152	5.1	9.3	32.9
4.0	24.82	14,892	10.5	18.9	67.2
0.0	48.21	28,926	20.4	36.8	130.6

CHAPTER XVI

FERMENTATION

The mixed dough, before it can yield a light, aerated loaf of bread, must first be fermented for a properly estimated period of time during which the yeast cells, which have been uniformly dispersed throughout the dough mass by mixing, act upon the available sugars, transforming them into carbon dioxide gas and alcohol. The most apparent outward change produced by yeast fermentation is a marked increase in the volume of the dough mass. As fermentation progresses, the dough rises in the trough to several times its original size and assumes a light, spongy character. At the same time the gluten is rendered more elastic and springy, being acted upon by a variety of factors, such as proteolytic enzymes originating in the flour and contributed by the yeast, the alcohol produced during fermentation, the various organic and inorganic acids that are formed, the increasing hydrogen ion concentration which develops in the dough, etc. All these factors alter the colloidal character of the gluten in such manner that it is able to form thin, gas retaining walls about the individual gas cells which are being formed and at the same time retains its extensibility and elasticity so that it can react to the stresses developing within the dough without rupturing. A dough in which the gluten has attained a state of optimum gas retention capacity and has developed a maximum elasticity and springiness is said to be mature. Just exactly what changes in the gluten produce the proper degree of maturity is not clearly understood at present. It is known, however, that a dough improperly matured either through insufficient fermentation or through over fermentation will not yield quality bread.

THE FUNCTION OF YEAST

Before considering the practical conduct of the fermentation process, it might be well to review very briefly the chemical reactions that occur in a fermenting dough. Yeast, like any living organism, requires certain foods before it can function properly; therefore such environmental factors as adequate amount of moisture, moderate temperatures, the proper degree of acidity, and an adequate supply of fermentable carbohydrates and assimilable nitrogenous substances as well as certain essential minerals form the basic requisites for a proper fermentation. Yeast

itself, during the course of fermentation, brings about changes in the medium, such as depletion of fermentable substances, accumulation of waste products in the form of carbon dioxide, alcohols, acids and esters, a modification of pH conditions, a mellowing of the gluten structure, etc. All these factors, in their totality, add up to a highly complex system whose study is rendered the more difficult in the case of dough by the fact that additional variables are introduced with different flours, different yeast races, and different formula additions.

The chemical reactions involved in the transformation of sugar into carbon dioxide and alcohol have been discussed in some detail elsewhere in this volume (*cf.* p. 124). While the primary physiological activity of yeast in a dough is that of fermentation, it also undergoes a certain degree of growth or multiplication. Earlier workers investigating this subject were hampered by a lack of suitable methods for counting yeast cells in doughs and little agreement existed between their results. It was not until Hoffman and co-workers (*16*) developed a standardized and accurate method of counting yeast cells in doughs that the effect of various factors on yeast growth in that medium could be reliably studied. These authors found that in a standard test dough in which the yeast content constituted 1.67 percent based on flour and which was fermented at a temperature of 80° F., there occurs practically no perceptible increase in yeast cell count during the first two hours of fermentation, the actual increase in cell numbers being on the order of 0.003 percent. The period of most vigorous yeast growth is between the second and fourth hours of fermentation when the yeast cell count increased by 26 percent. Between the fourth and sixth hours, the rate of yeast multiplication declines again to about 9 percent based on the original yeast cell count.

The effect of yeast quantity on the rate of multiplication was determined on the same standard dough with all variables except yeast being held constant. The results showed that the smaller the quantity of yeast in the dough the greater the percentage increase in cell multiplication. Thus, when only 0.5 percent of yeast was used, the cell count increased by 88 percent after six hours' fermentation, while when 2 percent of yeast was used, the corresponding increase was only 29 percent. It was further shown that a close direct relationship exists between the actual increase in the number of yeast cells and the loaf volume of the resulting bread.

The effect of ammonium chloride, ammonium carbonate and calcium sulfate on yeast growth was determined. All three mineral salts exerted a stimulating effect, though the degree of stimulation varied with the individual salts. Ammonium chloride was shown to be the best yeast nutrient of the three, being particularly effective when smaller quantities

of yeast were used. When ammonium chloride and calcium sulfate were used together, a cumulative nutritive effect on yeast resulted.

Yeast does not ferment all available sugars at the same rate or even at the same time, showing distinct preferences for the simpler, more readily fermentable sugars over the more complex sugars. Pelshenke and Koeber (*17*) determined sugar levels in doughs at various stages of fermentation in an attempt to establish the sugar balance in wheat flour doughs. They found that in yeast-free doughs there is a pronounced increase of reducing sugars as a result of the amylolytic and maltase actions of flour. In yeast doughs the yeast causes a rapid initial decrease of glucose and sucrose, while the maltose content continues to rise during the early period of fermentation. Thus the first stages of dough fermentation are supported primarily by the utilization of glucose and sucrose by the yeast. Maltose fermentation does not occur until the later stages of dough fermentation. These investigators were unable to detect a conversion of maltose to glucose prior to fermentation and conclude from this that maltose is fermented directly by the yeast. Quantitative calculation showed that 1 gram of yeast will ferment about 0.32 gram of glucose per hour during a normal fermentation.

Paralleling yeast fermentation are many other reactions of a chemical and biological nature. Thus the various enzymes naturally present in flour or added in the form of dough conditioners catalyze numerous hydrolytic reactions, bringing about progressive degradations of the starch, proteins and fats. Inorganic salts serving in the role of stabilizers, yeast foods and oxidants exert far-reaching effects in modifying the general character of the dough. It must be remembered that the liquid phase of the dough is not a simple solution in which the yeast cells are suspended, but represents a highly complex colloidal sol. Baker (*18*) has separated the liquid phase of dough by means of supercentrifuging and characterized it as a highly viscous solution which can be whipped to a stiff foam like the white of egg. According to this authority, this liquid carries in solution pentosans, soluble proteins which are mostly albumins and globulins of low molecular weight, carbohydrates, salts, enzymes and gases.

As fermentation progresses, certain definite changes occur in the physical character of the dough which are collectively designated as dough ripening or mellowing. Proper dough maturity or mellowness constitutes that point in fermentation when the dough possesses maximum spring and elasticity and will yield the best bread which the flour used is capable of producing. Dough maturity represents the sum total of all the reactions that take place during fermentation. These reactions are many and only the principal ones will be indicated very briefly in the following par-

agraphs. It should be borne in mind that most of these reactions take place simultaneously and that the order in which they are listed does not represent the actual sequence of their occurrence.

The two main end-products of yeast fermentation are alcohol and carbon dioxide. Alcohol, being a liquid at normal dough temperatures, becomes part of the liquid phase. While its general effects upon dough conditions are not well known, it is bound to have some influence upon the colloidal nature of the proteins since it is present in amounts which are by no means insignificant. Thus fresh bread, after most of the alcohol has been volatilized and driven off during baking, may still contain as much as 0.5 percent (*19*). The carbon dioxide evolved by yeast does not all remain in the gas state. Some of it combines with water to form carbonic acid, according to the following equation,

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

Carbonic acid is a weak, unstable acid which is very slightly ionized and hence contributes only immaterially to lowering the pH of the dough.

Enzyme hydrolysis proceeds from the time the dough is mixed until the enzymes are destroyed by the oven heat. The rates of enzymatic action are not constant throughout, being influenced by such fluctuating environmental factors as availability of substrate, pH value of the dough, and temperature. The amylases convert available dextrines into fermentable sugars and at the same time exert their starch hydrolyzing action. At first the starch granules damaged during the milling process are reduced to dextrines and sugar and eventually some of the whole starch grains are attacked by either a postulated "raw starch factor" or, as appears more likely, by alpha-amylase. Proteolytic enzymes act upon the proteins of the dough, reducing part of them to lower molecular weight nitrogenous substances, some of which are assimilated by the yeast. The over-all effects of the above enzymatic reactions are a softening of the dough, due partly to a reduction of the absorption capacity of the carbohydrate material and partly to the weakening of the gluten system. Other enzymes, such as the lipases and pentosanases are also active and are thought to aid amylosis by attacking the pentosan and lipid coating which cover the starch granules.

Since flour always contains lactic acid and acetic acid bacteria, these organisms make their presence felt by converting suitable substrates into lactic and acetic acids. Thus lactic acid bacteria ferment dextrose into lactic acid according to the equation,

$$C_6H_{12}O_6 \longrightarrow 2HC_3H_5O_3$$

Lactic acid is a fairly strong acid and, since it is produced in relatively large amounts in a fermenting dough, has a rather pronounced effect by

reducing the pH of the dough. A similar situation exists with regard to acetic acid bacteria which convert alcohol into acetic acid,

$$C_2H_5OH + O_2 \longrightarrow HC_2H_3O_2 + H_2O$$

Acetic acid is a rather weak acid and ionizes very slightly; hence its effect upon pH is less pronounced than that of lactic acid. It is also quantitatively of lesser significance. The pH of the fermenting dough is also strongly affected by the presence of ammonium salts in yeast foods, especially if the ammonia is bound to strong acids, such as hydrochloric acid and sulfuric acid. Yeast readily assimilates ammonia, which provides necessary nitrogen, and thus liberates the acids as shown by the following very greatly simplified equations,

$$\underset{\text{Ammonium sulfate}}{(NH_4)_2SO_4} + \text{yeast assimilation} \longrightarrow \underset{\text{Sulfuric acid}}{H_2SO_4}$$

$$\underset{\text{Ammonium chloride}}{NH_4Cl} + \text{yeast assimilation} \longrightarrow \underset{\text{Hydrochloric acid}}{HCl}$$

Sulfuric and hydrochloric acids both are very strong acids which ionize almost completely and hence yield a great amount of hydrogen ions. Their depressing effect upon the pH of the dough, even when the acids are present in very small amounts, is quite pronounced. Thus the pH of a freshly mixed dough is generally found to have an approximate value of 6 which may be reduced to as low as 5 at the end of fermentation as a result of the various reactions whose end-products are acids of various kinds and strengths. This reduction of the pH has a pronounced effect upon the hydration and swelling of the gluten, upon the rate of action of enzymes, and upon various chemical reactions involving organic salt formations and oxidation-reduction processes. Brown and Thomas (*19a*) have provided a highly readable summary of the chemical reactions of dough fermentation.

From this rather inadequate summary of reactions occurring during fermentation, many of which are still only partially understood, it is apparent that the fermenting dough represents a highly complex system whose balance may be readily upset by inappropriate handling. The control of dough fermentation is still based largely upon empirical knowledge, i.e., knowledge acquired by practical experience, rather than on a scientific recognition of all of the essential factors involved. Yet as scientific research discloses more and more of the numerous reactions that occur, and as the nature and significance of each reaction become more fully clarified, the problem of controlling dough fermentation in practice will be greatly facilitated.

A prerequisite to proper fermentation is a balanced dough such as is

obtained by correct mixing. Each flour requires a definite time period for the formation of a homogeneous mass and for the optimal mechanical development of this mass. The actual time required to attain this goal is dependent upon flour variety, temperature of mixing, speed of mixing, kind and proportions of materials used, and other conditions imposed. When the resultant balanced dough is subjected to fermentation, two groups of forces begin to operate, namely those of gas production and of gas retention. Gas production is principally an enzymatic reaction involving the starch converting amylases, maltase which splits the sugar maltose to glucose, and the yeast enzyme system zymase which ferments the sugar into carbon dioxide gas and alcohol. Heald (*20*) has enumerated the following factors as increasing gas production: (a) an increase in yeast concentration; (b) addition of sugar or diastatic malt to flours which are deficient in either of these; (c) the use of yeast foods up to a certain amount; and (d) high temperatures up to 95° F. Factors which decrease gas production include: (a) salt; (b) excessive amounts of yeast foods; and (c) excessively high temperatures. High speed mixing and normal ranges of absorption have no effect on gas production. The factors governing gas retention are more numerous and diverse, involving proteolytic enzymes, chemical and physical means such as minerals, moisture, hydrogen ion concentration, bleaching agents, oxidizing agents, etc., and mechanical factors such as stretching under gas evolution, punching, dividing, rounding and molding. As Clark (*21*) has stated, "The objective to be accomplished during the fermentation division of the bread making process is to generate sufficient gas for maximum aeration and to disperse properly the colloidal structure of the dough so that a maximum amount of the gas will be retained."

The principal task of the baker is to so control his fermentation that the forces of gas generation and gas retention coincide as closely as possible. If the peak of gas production is reached before the elasticity of the dough is at the optimum, then much of the gas is dissipated and not enough will be left to properly aerate the dough when its extensibility is highest. On the other hand, if dough reaches its optimum gas retention capacity before gas production is at its highest rate, much of the gas will be lost subsequently. Hence the aim of fermentation control is to have gas production capacity and gas retention capacity develop at a parallel and even rate. "When both peaks are reached at the same time there frequently is combined in one loaf the largest volume together with the best grain, texture, crust color, and other loaf characteristics which the flour in question will produce" (*21*). Most flours yield a range of fermentation time over which gas production and gas retention are properly balanced and this range may be properly designated the fermentation

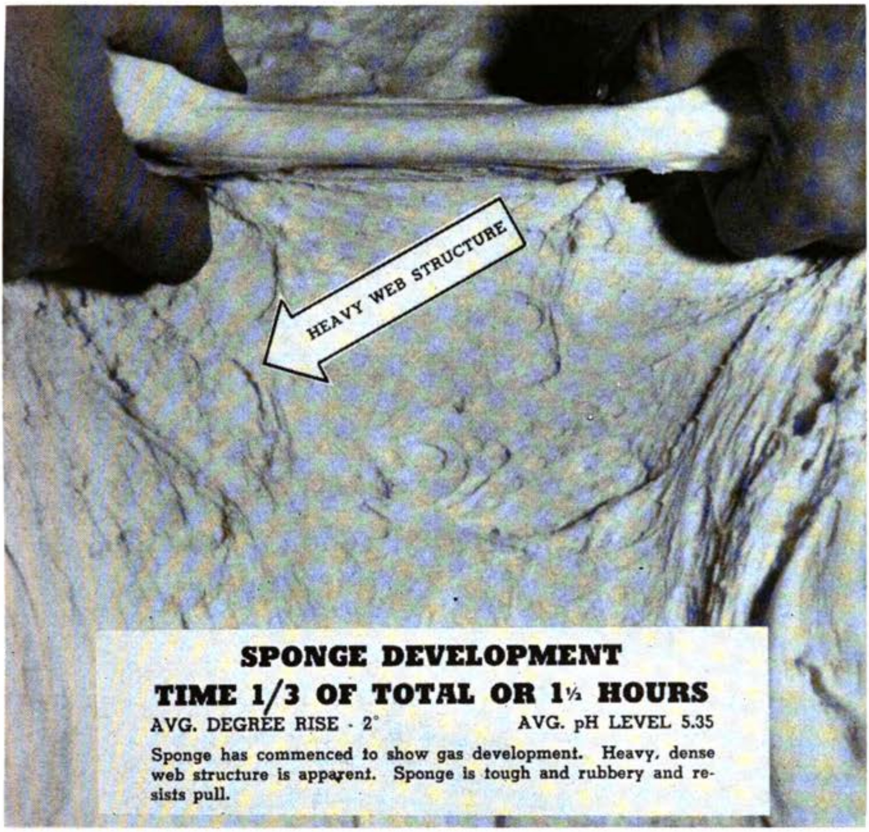


FIG. 70—Appearance of sponge after a fermentation time of 1.5 hours. (*Courtesy Amer. Soc. of Bakery Engineers.*)

tolerance of the flour. Since fermentation is influenced by many factors and environmental conditions, it is evident that one and the same flour may have a rather narrow range of fermentation tolerance under one set of conditions and quite an extended range of fermentation tolerance under a different set of conditions.

Swortfiguer (*4*) has recently provided a detailed description of the visual changes that occur in sponge characteristics in the course of fermentation. Assuming a sponge fermentation time of 4.5 hours, accompanied by a 10° F. temperature rise, the so-called "web-formation" or "web-structure" which is formed when the top of the sponge is pulled back will show a certain characteristic appearance. In a sponge which has gone through about one-third the required fermentation period, this web structure, as shown in Figure 70, will be heavy and dense and the sponge in general will have a rubbery feel when pulled back. As fermentation pro-

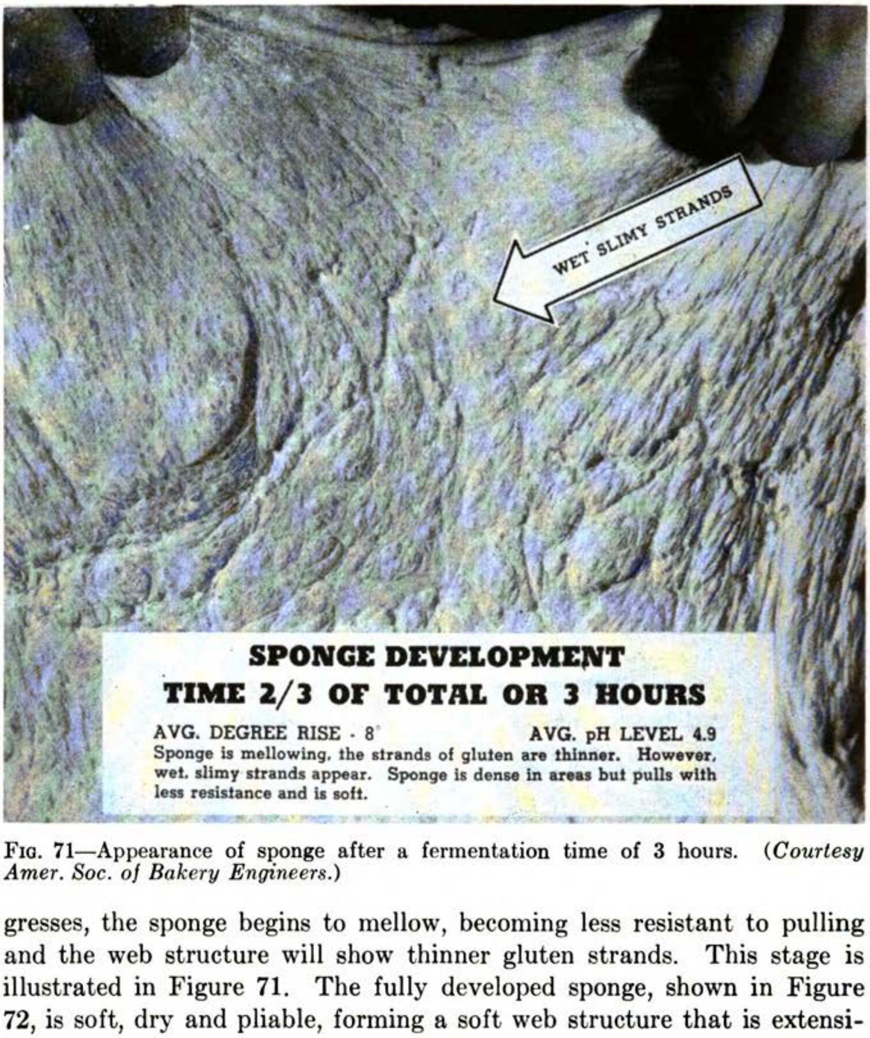


FIG. 71—Appearance of sponge after a fermentation time of 3 hours. (*Courtesy Amer. Soc. of Bakery Engineers.*)

gresses, the sponge begins to mellow, becoming less resistant to pulling and the web structure will show thinner gluten strands. This stage is illustrated in Figure 71. The fully developed sponge, shown in Figure 72, is soft, dry and pliable, forming a soft web structure that is extensible without toughness or hard pull. In a sponge fermented beyond this point, the web structure loses its soft, dry appearance and becomes overgassed, bucky and wet. This change is shown in Figure 73.

Following the remix, in which the remainder of the dough ingredients are combined and mixed with the sponge, the resultant dough is subjected to a secondary fermentation, normally referred to as floor time. Dough fermentation passes through distinct phases in a manner similar to sponge fermentation, i.e., the dough must undergo a process of aeration and development before a satisfactory loaf of bread can be obtained from it.

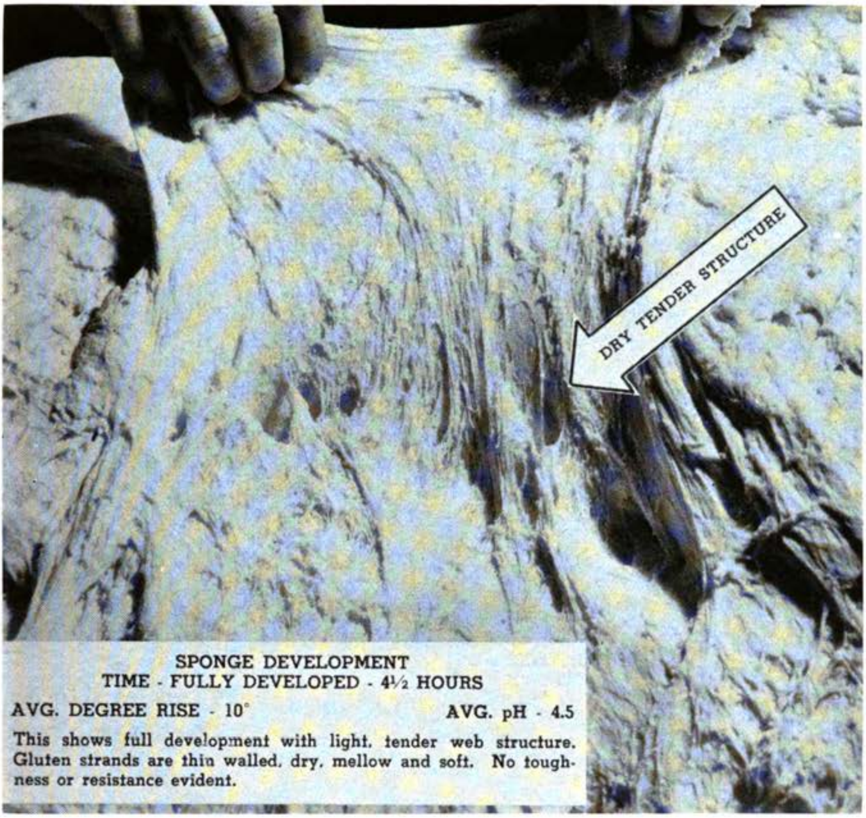


FIG. 72—Appearance of sponge after a fermentation time of 4.5 hours representing optimum development. (*Courtesy Amer. Soc. of Bakery Engineers.*)

In the subsequent figures, also taken from the data by Swortfiguer, the modification of dough properties is clearly illustrated. In Figure 74, which is that of a dough just out of the mixer, the dough is seen to be highly extensible and, if pulled out sufficiently, breaks with a ragged tear. As fermentation progresses, the dough assumes a somewhat drier feel, loses its surface sheen and, when stretched, is less extensible and breaks more cleanly. The dough mass also assumes a more spongy appearance (Figure 75). The fully matured dough shown in Figure 76 has developed a fine, thin web structure, similar to that observed in the ripe sponge. The matured dough, when pulled, breaks quickly with short clean fractures. If floor time is extended beyond this point, the dough will turn wet and sticky (Figure 77) and exhibit a pronounced bucky character.

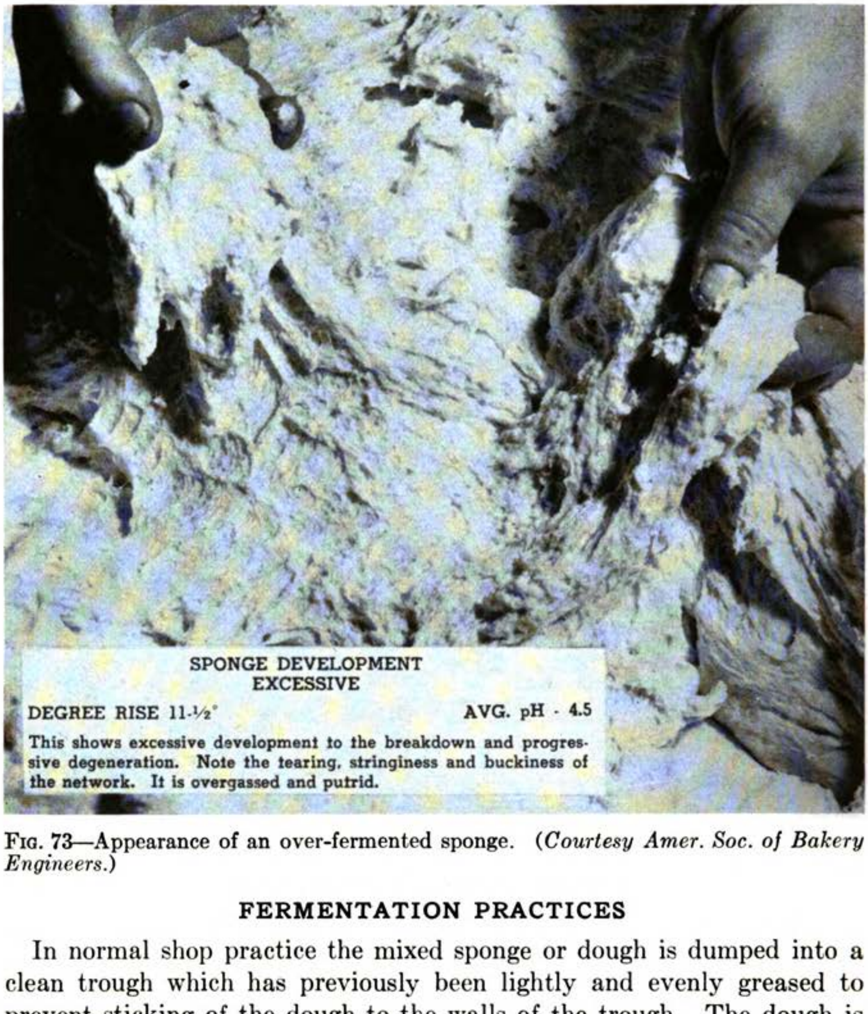


FIG. 73—Appearance of an over-fermented sponge. (*Courtesy Amer. Soc. of Bakery Engineers.*)

FERMENTATION PRACTICES

In normal shop practice the mixed sponge or dough is dumped into a clean trough which has previously been lightly and evenly greased to prevent sticking of the dough to the walls of the trough. The dough is pulled over and flattened so that it presents an even smooth top surface. The amount of dough placed in a trough is of some importance. Generally speaking, in the case of straight doughs, the practice is to allow 2 feet of length of a standard size trough for each 100 lbs. of flour in the dough. In the case of sponge doughs, which are permitted to rise to a considerably greater volume, twice the amount of trough space, or four feet, should be allowed for each 100 lbs. of flour in the sponge. In instances where trough capacity is excessive, the use of space boards is recommended to confine the dough within the proper space. The reason for maintaining a proper relationship between dough volume and trough

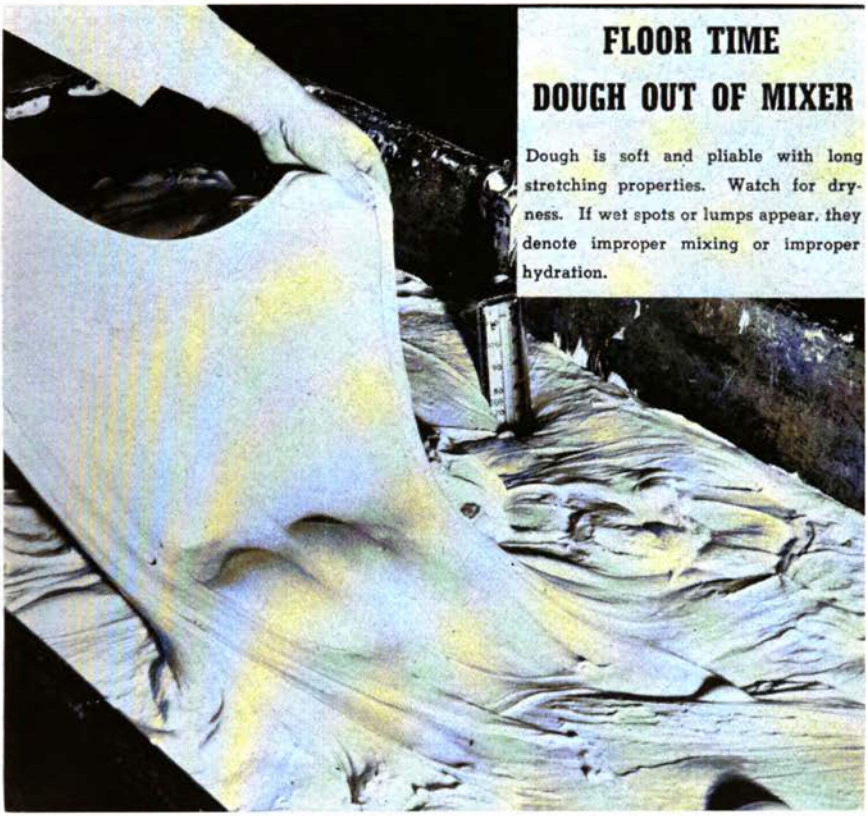


FIG. 74—Appearance of dough out of mixer. (*Courtesy Amer. Soc. of Bakery Engineers.*)

capacity is that if the trough is too small for a given dough, the dough will overflow on rising and cause obvious difficulties, whereas if the trough capacity is too large, the dough will spread out rather than rise and thereby fail to ferment properly.

The troughs containing the mixed doughs are then wheeled into the fermentation room where they remain for a given period. This room should be properly conditioned with respect to temperature and humidity so as to provide an optimum environment for the doughs. In general, a temperature of around 80° F. and a relative humidity of 75° percent will be found most satisfactory for this purpose. Very much cooler temperatures will have a retarding effect upon the fermentation rate, prolonging the fermentation period unduly. Temperatures much higher than 80° F., on the other hand, will accelerate the fermentation rate and increase the danger of the occurrence of so-called "wild fermentations" involving wild

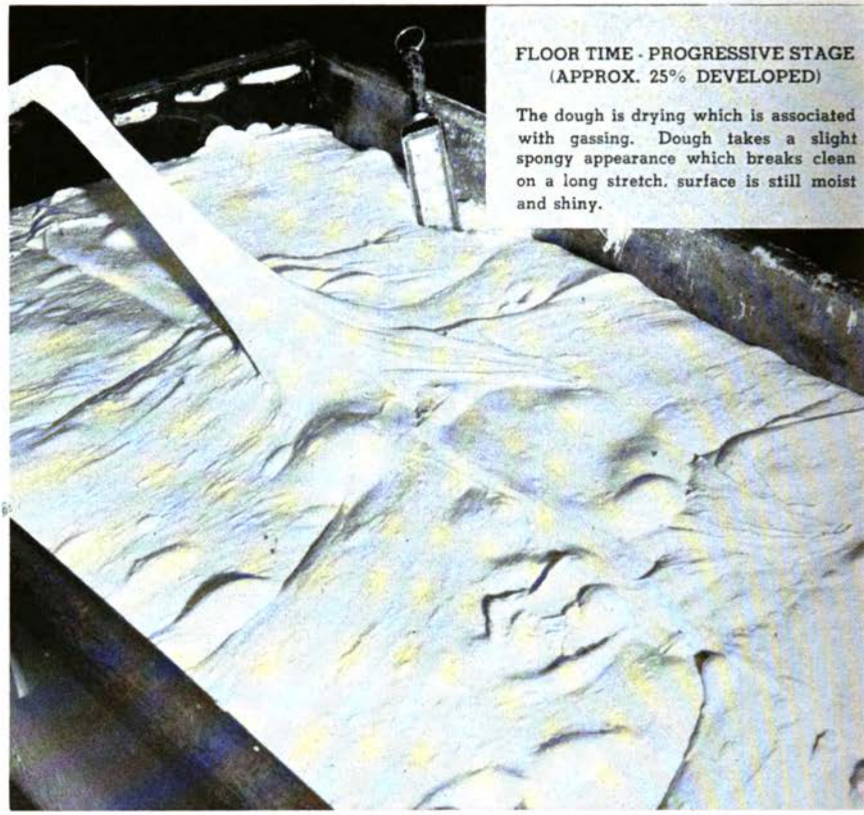


FIG. 75—A dough which has received about one-fourth of its required floor time. (*Courtesy Amer. Soc. of Bakery Engineers.*)

yeasts, lactic acid and acetic acid bacteria, mold and rope organisms. Controlled humidity is of equal importance. An atmosphere whose relative humidity is less than 70 percent will have a drying effect upon the dough surface, causing it to form a more or less noticeable crust which not only acts to retard the fermentation but also leads to ultimate irregularities in the baked product. In general it is good practice to aim at a relative humidity in the fermentation room which corresponds to or is slightly higher than the numerical value of the percent moisture in the dough. In this connection it is important to remember that the total moisture of a dough comprises both the absorption, or the amount of liquid added during dough mixing, and the original moisture content of the flour which normally ranges from 11 to 13 percent. Thus a dough made from flour having a moisture content of 12 percent and using 63 percent of ingredient water based on flour weight would contain a total

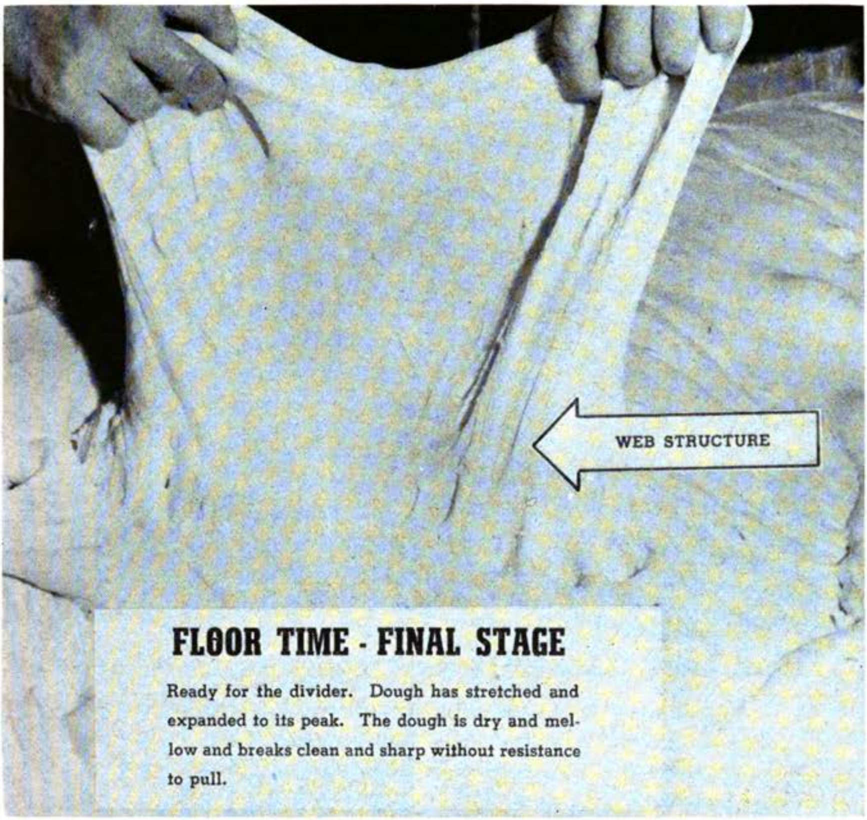


FIG. 76—Appearance of a fully matured dough. (*Courtesy Amer. Soc. of Bakery Engineers.*)

of 75 percent moisture based on flour. The corresponding relative humidity of the dough room should therefore approximate 75 percent. Precautions should also be taken to avoid the occurrence of drafts within the room as these are responsible for fluctuations in the temperature of the doughs and hence for irregular fermentations.

A sponge should be set to ferment at a temperature of 74 to 78° F., depending upon shop conditions. As a rule, it is desirable to have the sponge on the cool side and to use an adequate amount of yeast. When approximately 2 percent of yeast is used, the fermentation will proceed rapidly and vigorously, bringing about a full maturation of the sponge in a relatively short time of 3 to 4½ hours under normal conditions and without causing an excessive increase in its temperature. In a properly conditioned dough room the increase in sponge temperature should not exceed 8° F. for the entire fermentation time so that a sponge set at

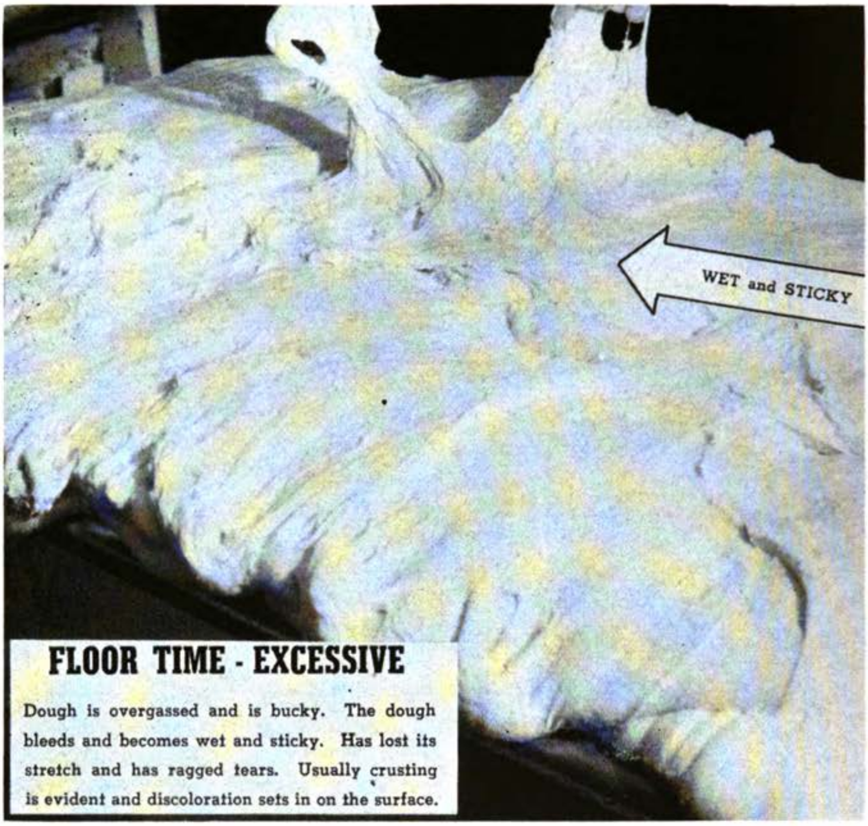


FIG. 77—Appearance of a dough that has received excessive floor time. (*Courtesy Amer. Soc. of Bakery Engineers.*)

76° F. should return to the mixer at 84° F. In determining the length of time the sponge requires to reach proper maturity, the so-called drop or break constitutes a vital point. Normally a sponge will rise to about 4 to 5 times its original size and then recede in volume. This diminution in volume, constituting the drop or break, is quite marked and forms the point from which further fermentation time is calculated. Depending upon whether young or old sponges are desired, the drop is taken to mark the completion of 75 percent to 66 percent, respectively, of the total sponge fermentation time and the sponge is permitted to stand the corresponding additional time after this point has been reached. Generally, older flours require younger sponges and in such cases the post-drop time is reduced to 25 percent. Thus if the sponge made from older flour required $2\frac{1}{2}$ hours to reach maximum volume, it would then be permitted

to stand an additional 37 minutes, which represents one-fourth of 2½ hours. The total sponge fermentation time would therefore be 3 hours and 7 minutes. The fully fermented sponge is then returned to the mixer and made up into the final dough which is then subjected to additional fermentation of a relatively short time. The dough will be fully matured when it has developed shortness to a sharp pull and a rather dry feel to the touch. This stage is normally reached after a floor time of 20 to 45 minutes under average conditions. Warmer environmental temperatures will reduce the floor time and may eliminate it altogether, while cooler temperatures tend to lengthen it.

Straight doughs should be set at a slightly higher temperature than sponges, i.e., within a range of 77 to 79° F. The accelerating effect of the higher temperatures is desirable in this case since the straight dough contains all ingredients, some of which, such as milk solids and salt, have a retarding effect on yeast action. Dough fermentation, as a rule, proceeds at a somewhat slower rate than does sponge fermentation so that straight doughs require a longer period to reach proper maturity than do sponges in their primary fermentation stage. On the other hand, when the fermentation periods of the sponge and of the sponge dough are added, they normally represent a longer total time span than does straight dough fermentation.

Straight doughs differ from sponges not only in their fermentation rates, but also in their manipulation during fermentation. Generally, the practice is to leave the sponge undisturbed until it is ready for return to the mixer. In contrast to this, straight doughs receive periodic punching or turning during which a good portion of the evolved carbon dioxide gas is expelled, thereby reducing the dough volume. While actual punching in the form of vigorous kneading of the dough is still resorted to in many cases, the recommended practice is to turn and fold the sides of the dough well into the center. Vigorous punching with well matured flours has a tendency to yield bucky doughs which subsequently prove difficult to handle. Folding, on the other hand, avoids this problem and at the same time exerts a highly beneficial effect in that it equalizes the temperature throughout the dough and thereby assures a more uniform fermentation, reduces the retarding effect of excessive accumulation of carbon dioxide within the dough, introduces atmospheric oxygen with its stimulating effect on yeast action, and aids in the mechanical development of the gluten by the stretching and folding action involved in this process, thereby increasing the gas-retaining capacity of the dough. It is this last effect which appears to be of primary importance, according to Elion (*22*). Studies carried out by this investigator on gas production

and gas retention have shown that gas production is not constant during fermentation but increases at first until a maximum rate is reached and then decreases. The increase in dough volume corresponds to gas production only during the first hour of fermentation. Following this point there is a marked decline in the rate of volume increase. Thus a dough permitted to go through fermentation without punching will suffer a considerable loss of carbon dioxide. If, however, the dough is punched back or turned and folded at the right time, its gas retention capacity is increased to a point where practically no gas loss occurs. In practice, the rate of dough expansion is greatly accelerated following punching back which has led to the assumption that this operation results in an increase of the fermentation rate. Elion's results would indicate that there is no significant effect upon the rate of fermentation or gas production, the beneficial effects of punching back being almost entirely limited to the gas retention properties of the dough.

The correct time at which the dough should be punched back or turned for the first time is of considerable importance to dough development and is usually determined by inserting the hand into the dough, withdrawing quickly, and observing the dough's behavior. If the dough reshapes itself, i.e., shows only a very slight recession, it is ready to be turned and folded. This point is usually considered as constituting the completion of 60 percent of the total fermentation time. The dough is then again turned after one-half the time which elapsed between the start of fermentation and the first punch, which thus represents 30 percent of the total fermentation time. During the remaining 10 percent, the dough is sent to the bench or the divider. In practice, this procedure works out somewhat as follows: a dough is found to require the first punch after 120 minutes. Since this time span represents 60 percent of the total fermentation time, the latter amounts to 120 : 0.60, or 200 minutes. The second punch, coming in half the time required for the first punch, will be given the dough after an additional 60 minutes which, it is seen, represents 30 percent of the total fermentation time. During the remaining 20 minutes, or 10 percent of the total time, the dough is taken to the divider.

The above procedure is intended merely to indicate a general practice and cannot, of course, be applied under all conditions. The character of the flour plays an important part in determining actual fermentation times. Old flours which are thoroughly matured normally require shorter fermentation times and less frequent punching or folding than do so-called "green" or immature flours. To reduce the fermentation time, the point at which the first punch is indicated is taken to represent the completion of a full two-thirds or even three-fourths of the total fermenta-

tion time, and the second punch is omitted. This procedure will yield so-called "young" doughs which are required to produce satisfactory results with flours which have undergone long storage. Older doughs, on the other hand, are obtained by having the time to the first punch represent a lesser proportion of the total fermentation time and giving the dough a series of periodically spaced turnings or punches. This is usually required with strong flours of high protein content, or lower grade flours produced by longer extractions. Such flours may require four or five punches, in which case they have a tendency to give rise to bucky doughs. This may be corrected by slightly overmixing the doughs or by increasing the absorption somewhat. A slight increase in the dough temperature will also act to accelerate fermentation and thereby reduce the total time. When green, immature flours are encountered, difficulties may arise with marked slackening of the fermenting doughs. In this case, increasing the number of punches will tend to stiffen the dough. Other corrective measures include a slight increase in the amount of yeast food, and of both yeast food and yeast. In both instances, the salts of the yeast foods will exert a tightening effect upon the gluten and also accelerate the rate of yeast fermentation, thereby shortening the fermentation time.

VARIATIONS IN FERMENTATION TIME

The fermentation time adopted as optimum in a given shop represents the sum total of interrelated effects produced by a variety of factors, such as character of flour, amount of yeast, temperature, formula ingredients, level of oxidation, and others. Once practical experience has established the most suitable handling procedure for a certain type of flour, it is generally closely adhered to in the interest of quality and uniformity.

Occasions may arise, however, when it is necessary to change the accepted fermentation time in either direction. To meet such exigencies certain rules involving changes in yeast quantity and temperature have been developed which work reasonably well, but which should always be regarded as merely temporary expedients. In other words, any drastic deviation from an accepted procedure which has yielded optimum results is bound to reflect itself in reduced quality. Hence, while it is possible to shorten or lengthen the fermentation time by proper adjustments in the amount of yeast and of the fermentation temperature, the resultant bread will not come up to normal standards.

Experience has shown that there exists an inversely proportional relationship between the amount of yeast and fermentation time. Thus a reduction in the amount of yeast will result in a longer fermentation

time, while an increase in the amount of yeast will shorten the fermentation time. The actual quantitative changes required are obtained by the following simple equation:

$$\frac{y \times t}{n} = x$$

where y = percent of yeast normally used,
t = normal fermentation time
n = new fermentation desired
x = amount of yeast required for new fermentation time.

How this equation works in practice may be seen from the following example: Assuming that with 1.5 yeast a given flour yields best results with a 4 hour fermentation time and that it is desired to reduce the fermentation time to 3 hours, then by substitution we arrive at the following equation:

$$\frac{1.5 \times 4}{3} = 2\%$$

Under the above assumptions, therefore, the percentage of yeast would have to be increased to 2 percent in order to attain a reduction to 3 hours in the fermentation time.

Rules of this nature have, of course, their limitations. Thus, using again the above conditions, if the fermentation time were to be reduced to only 2 hours, 3 percent of yeast would be required. However, it is no longer possible to produce quality bread with such high yeast additions since the gluten will fail to develop properly and a noticeable yeast flavor will remain in the finished product. Generally speaking, fermentation times may be varied up to a maximum of 30 percent in either direction by adjustment in amount of yeast. If greater variations are required, adjustments in other factors must also be made, such as in temperature and amount of yeast food. A generally accepted rule is that a 1° F. change in temperature is equivalent to 15 minutes in straight dough fermentation. A dough out of the mixer 1° warmer than normal will therefore, under average conditions, require about 15 minutes less fermentation, and vice versa. Here again, practical considerations limit the extent to which fermentation time may be altered to about 45 minutes if no other changes are involved.

With respect to yeast food, no clear-cut rule can be advanced. Very generally speaking, when shorter fermentation times are desired the amount of yeast food should be increased, while in the case of longer fermentation times the yeast food should be decreased. A safe procedure

is to make these changes gradually, preferably in steps involving variations of 25 percent of the original amount.

CABINET FERMENTATION

While sponges are normally fermented in open troughs, some bakers have recently introduced a modification in this procedure by conducting sponge fermentations in closed cabinets. These cabinets, constructed of a variety of materials ranging from plywood to steel, may be likened to miniature fermentation rooms just large enough to accommodate one trough each, with the ceiling some 10 to 12 inches above the maximum height of the sponge. As a rule, no provisions are made for either temperature or humidity control. Some of the bakeries who have installed such cabinets have obtained superior results, while others have been unable to detect any advantage in the method. Since the method has elicited considerable interest among bakers, it will be worthwhile to review briefly some of the extensive studies which have been made on cabinet fermentation.

Johnson (*23*) conducted laboratory experiments on small doughs in which different gas mixtures above the fermenting sponge were used. Changing the atmosphere above the sponge had no effect upon the rate of expansion and height of the sponge. However, when an atmosphere high in carbon dioxide was used with a three-hour sponge, a better bread resulted than when the sponge was fermented in a normal atmosphere. Sponges fermented in high concentrations of oxygen or nitrogen gave poor handling doughs.

Schoonover, Freilich and Redfern (*24*) conducted a comparative study of open trough and cabinet fermentation under varying conditions of dough room temperature and humidity, sponge temperature, sponge time, and amount of yeast. Their results were largely negative and indicated that, with the exception of slight mellowing effects, cabinet fermentation offers no advantage over open troughs in a controlled dough room at 80° F. Only when the dough room temperature was much lower than the starting temperature of the sponge did cabinet fermentation show definite advantages over open trough fermentation and here the favorable results could be attributed primarily to the insulating effects of the cabinet in a cool room.

Sullivan and Richards (*25, 26*), on the other hand, observed that even when both temperature and humidity of the dough room are regulated, the cabinet doughs always maintain their superiority. They found that cabinet doughs took an average of 2 percent more absorption. The sponges had finer and more uniform pores. At remixing they were drier and broke up more easily, allowing a few minutes shorter mixing time.

The outstanding difference between cabinet and open sponges they found to be in the machining. Cabinet doughs were drier, more pliable and extensible, and machined more smoothly with less dusting flour. The bread from the cabinet doughs always scored slightly higher than the bread from the open doughs, mainly due to more uniform, finer grain and thinner cell walls. Also, there was a slightly more tender crumb and better crumb color. No significant differences were noted in loaf volume, symmetry, or break and shred between the two procedures.

These authors made numerous gas analyses of the atmosphere above the fermenting sponge in the cabinet which disclosed that no significant amount of carbon dioxide is released until the sponge breaks. From this they concluded that the superiority of the cabinet sponges is due to the greater concentration of carbon dioxide over the sponge during the period between the breaking of the sponge and the time of remixing. They found that the best results were obtained when the critical concentration of carbon dioxide at this period was approximately 20 percent, and that when open sponges were fermented in an atmosphere containing the same carbon dioxide concentration they yielded results similar to cabinet sponges. When sponges are fermented in an atmosphere of either oxygen or nitrogen, poor machining and inferior bread result. This is taken to indicate that the sponge is permeable to the gases above it, and because of the greater solubility of carbon dioxide in water, it is probably more permeable to carbon dioxide than oxygen or nitrogen.

In discussing their results, these authors advance the following partial explanation of the effects of cabinet fermentation:

"Fermentation consists of a number of oxidation-reduction reactions of the trioses which are formed by the cleavage of glucose. These reactions depend on several enzyme systems whose delicate balance may be shifted by means of the gaseous environment, or by the presence of certain compounds or groups capable of interference or protection of some of the energy transfer systems. The —SH groups, for instance, undoubtedly have, as one of their functions, the protection of certain systems against oxygen injury and, hence, act as regulators of the fermentation reactions. Before we can understand the reason for some of the over-all effects observed in cabinet fermentation, it will be necessary to study certain of these specific enzyme systems. It is quite probable that the atmosphere present above the sponge will influence the rate and the course of many of these reactions since, apparently, the sponge is permeable to the gases above it. . . . It is evident that carbon dioxide has a specific effect and this effect is much more important than the maintenance of a state of anaerobiosis. Because of the carbon dioxide produced in the fermentation, anaerobiosis is present, to a large and perhaps sufficient degree, in

sponges fermenting in air. The increased amount of carbon dioxide presumably present in the sponges from the cabinet procedure during the period after the break and before the remixing of the sponge may exert its effect by combining chemically with the basic amino groups of the protein, or by changing the course of certain enzyme reactions because of its replacement of air in the fermenting dough. The phenomenon of carbon dioxide retention by proteins such as serum is well known. As measured by barium hydroxide titrations, a greater carbon dioxide retention was found in the cabinet sponge than in the open sponge. Until more research is done on the specific mechanism of the action of increased concentrations of carbon dioxide on fermenting sponges, it is not possible to explain fully the effects observed."

Subsequent to the publication by Sullivan and Richards of these results, Garnatz, Hodler and Rohrbaugh (*27*) subjected the cabinet fermentation procedure to an extensive investigation under practical shop conditions. They were unable to detect a significant difference between the open trough and cabinet sponges and doughs in rate and height of rise, sponge time, absorption, machineability of doughs and general bread characteristics. The only advantages they concede to cabinet fermentation are the ability of the cabinet to insulate the sponges against significant fluctuations in dough room temperature and of automatically providing sufficient humidity to prevent crusting of the sponges.

FERMENTATION LOSSES

It is common practice in bakeries to determine the so-called fermentation loss of sponges and doughs by either calculating the total formula weight and comparing it with the determined weight of the fermented sponge or dough, or by weighing the mixed dough before and after fermentation. There will always be found a slight loss of weight in the fermented dough which may amount to as little as 0.5 percent or to as much as 3 to 4 percent. Under average conditions, a weight loss of 1 percent is considered normal. Fermentation losses determined in this manner, however, represent only apparent instead of actual losses as becomes evident from the following considerations and data. Loss of weight by the sponge during fermentation is largely a matter of moisture evaporation which can be made up by a slight increase in doughing water during dough mixing. Furthermore, depending upon the relative humidity maintained in the fermentation room, this loss in weight of the sponge may be greater or smaller and therefore actually reflects the prevailing humidity conditions. While some carbon dioxide does evolve from the sponge, its weight is too small to be of much consequence. Real fermentation loss does not become apparent until the baking process is reached.

Here the volatile substances, such as alcohol, carbon dioxide, acids, esters and similar compounds which result from yeast metabolism of sugar and nitrogenous substances, escape from the baking dough under the influence of the oven heat. That such losses may be significant has been shown by Eisenberg (*28*), who investigated the effect of malt addition to sponges. The higher the malt increment, the more vigorous was the fermentation and the greater the volume of gas produced. The relationships between malt increment, total gas produced, loaf weight and loaf volume found by this investigator are shown in the following table.

TABLE 105. FERMENTATION LOSS AS A FUNCTION OF MALT FLOUR ADDITIONS TO THE SPONGE
(All data are calculated to 100 g. total flour)

Malt flour gms	Total gas cc	Loaf weight gms	Loaf volume cc
0.0	884	134.1	568
0.1	1,180	132.6	581
0.2	1,300	131.6	589
0.3	1,370	130.9	604

Fermentation losses may be minimized by a judicious selection of sponge ingredients and fermentation conditions which will limit the extent to which yeast can convert non-volatile ingredients to volatile fermentation products. Thus decreasing sponge time or temperature will minimize fermentation loss. Low sponge percentages will have the same effect. Using flours low in diastatic activity for sponges and omitting malt supplements in the sponge stage will generally be found to be the most effective procedure for reducing fermentation losses. Eisenberg points out that bakeries in changing from high to low fermentation loss conditions may expect an increase in bread yield per given quantity of raw materials of as high as 4 percent. This is of economic significance and warrants a re-evaluation of the "fermentation loss" of standard bakery practice.

CHAPTER XVII

DOUGH MAKE-UP

DIVIDING

The fermented doughs should be taken immediately to the divider or scaling bench for prompt scaling off. It should always be borne in mind that the end of the floor time does not terminate the actual fermentation that occurs in the dough, but that the latter continues unabated and frequently at an accelerated rate. The longer the time required to scale off the dough, the greater is the difference in the general character of the

FIG. 78—Modern make-up department consisting of eight-pocket divider, rounder and intermediate overhead proofer. Dough trough is shown in the automatic lift above divider hopper. (*Courtesy Fuchs Baking Co.*)

dough pieces from the first portion and the last portion of the dough being scaled off. The difference actually encountered is determined to a considerable degree also by the length of the fermentation period adopted, being as a rule greater with short time doughs than with long time doughs. This is one of the factors that accounts for the greater uniformity of bread that is obtained with long time doughs. In hand scaling, either the entire dough if it is small, or large portions of it if it is large, are placed on the bench and cut into proper size pieces, each of which must be scaled to check its weight. In machine dividing the entire dough is dumped from the trough into a chute leading to the divider hopper. From there it flows into a dough chamber of proper size where a plate or dough knife cuts off the amount filling the chamber from the rest of the dough batch. The severed dough piece is then compressed into a series of pockets whose volume is accurately adjusted by the operator. From there the dough piece is deposited onto a conveyor belt for transfer to the rounder. It is obvious that the dough receives a great deal more mechanical punishment in machine dividing than in hand scaling; hence, as a general rule, machine divided doughs should be younger than hand scaled doughs. Greatest damage by the gluten is incurred during that stage of operation where the dough is compressed into the pocket, especially if this is done at a slow rate. To minimize the adverse effect of this operation, the dough should flow rather freely, possess a high degree of pliability, and show a minimum of buckiness. Such doughs require the use of strong flours, a correct mixing procedure and a fermentation held on the young side. The speed at which the divider is operated has an important bearing on the subsequent behavior of the dough pieces. In practice, the optimum divider speed will generally be found to be 12 strokes per minute. Speeds much in excess of this rate subject the dough to too much punching and also reduce the useful life of the machine itself through increased wear and tear on its moving parts. On the other hand, if the speed of operation is reduced very much below the optimum, the more marked squeezing action that results causes an excessive deterioration of the gluten, especially in bucky doughs. While in general young doughs are better able to withstand the abusive action incident to higher speeds, such as within the range of 16 to 18 strokes per minute, these rates are not recommended except in instances where it is imperative that the dough be divided quickly. In the case of older doughs the normal rate of 12 strokes per minute should never be exceeded.

The importance of the time element in dividing to product uniformity has already been mentioned above. It is good practice to limit the individual dough batches to a size that will permit their scaling off within 15 to 20 minutes. This means, in the case of a one-pocket divider

operating at an optimum rate and set to scale 18 ounce dough pieces, that the individual dough batches should be restricted to weights of 200 to 270 lbs. With dividers having two or more pockets, correspondingly larger doughs are in order. The principal reason why prolonged dividing operation leads to irregularities in production is that it is in most instances impossible to control the temperature of the dough in the divider hopper. Not only does the temperature of the dough tend to rise because of the fermentative action that proceeds within the dough, but the dividing operation is usually also carried out in a warmer section of the plant which has an additional warming effect. Doughs which warm up in the divider chute or hopper consequently undergo an increase in their fermentation rate which may lead to the development of high acidity, pronounced stickiness and excessive dough age. Doughs with these undesirable characteristics cause irregularities in scaling and result in dough pieces of varying weights. When baked, the loaves will be marked by a streaky grain, poor crust color, and reduced keeping quality.

Because there are certain evaporative losses during the baking process, the scaled dough piece must be heavier than the weight of the finished baked product. Depending upon shop conditions, the extra weight allowance is normally within the range of 1.5 to 2 ounces for each pound of baked bread, so that in the case of the one pound loaf, the scaled dough piece will weigh 17.5 to 18 ounces. Because most states have rather strict weight and labelling laws, the importance of accurate scaling is obvious. For this reason a sensitive scale should be provided adjacent to the divider with which the operator can frequently check the weight of the individual pieces of scaled dough. This will guard against short weight on the one hand, and against losses through over-weight on the other. It should also be kept in mind that as dividing proceeds, the dough in the divider hopper continues to expand through gas production and therefore will show a progressive reduction in weight per given volume. This requires periodic upward adjustment in the size of the scaled dough pieces if their weight is to remain constant.

Efficient divider operation presupposes proper setting of the unit. When either the pockets or the compartments are incompletely filled with dough the machine usually develops a discernible knocking which reveals the existence of this condition. The remedy lies in more freely flowing and pliable doughs or the proper adjustment of the divider. Frequently this condition calls for a change in the setting of the ram, either to provide more play or to reduce its movement. A fairly good indication of whether or not a divider is properly adjusted and operated is obtained by observing the behavior of the dough in the hopper which should exhibit a minimum of jump at each stroke. Correct lubrication of the

compartments is also of importance to the satisfactory operation of the divider. The oil used for this purpose should be stable, odorless and tasteless. Excessive lubrication should be guarded against as it is one of the causes of the development of large holes in the crumb of the baked product. When efficiently operated, a divider should show a loss of less than 1 percent of the total dough charge. Under normal practical conditions, a maximum divider loss of 2 percent may prove acceptable, although every attempt should be made to keep the loss to a minimum.

Hand scaling is still practiced in a large number of small shops. Its principal advantage is that it subjects the dough to far less mechanical abuse than does machine scaling so that weaker flours, giving rise to more delicate gluten, can advantageously be used in hand shops whereas they would be unsuitable for mechanical make-up operation. Hand scaling, in general, requires just as much care as does machine scaling. Thus it must be carried out rapidly to prevent pronounced differences in age characteristics between the first and the last portion of the dough. Bread and roll doughs should be worked away within a maximum period of 20 minutes to minimize irregularities of production. Richer doughs, such as are used for yeast-raised sweet goods, may be kept on the bench for somewhat longer periods since these doughs possess a reduced fermentation rate. While doughs should be scaled rapidly, the operation should be performed with care. The number of cuts per dough piece should be kept to a minimum, otherwise defects in the finished baked product will result. Also, dusting flour should be used sparingly in order to avoid streaks in the crumb of the bread.

ROUNDING

Following the dividing or scaling operation each individual dough piece is rounded into a ball either by hand or by a special machine called the rounder. This machine performs a highly essential task in a speedy and efficient manner. When the dough is cut either by a divider or by hand, it loses a certain amount of carbon dioxide gas through the punishment that is inherent in this operation. This loss of gas reduces the pliability of the dough piece so that it is difficult to mould into the proper form for placing into the baking pan. Each scaled dough piece must therefore be permitted to regain some of the gas it has lost. If a scaled dough were allowed simply to rest in the form in which it emerged from the divider, a great deal of the newly formed gas would pass through the raw surfaces created by the cutting action and would hence be lost. The principal function of rounding is therefore to coat each dough piece with a skin that will retain the freshly produced gas and thereby aid in raising the dough piece. Another advantage of rounding is that by putting a skin

around each dough piece it largely eliminates the dough's stickiness which would otherwise cause difficulties during subsequent handling. Furthermore, by imparting the same shape to each dough piece and by bringing a measure of gas cell redistribution within each ball, greater uniformity of the loaf symmetry and grain is ultimately attained in the baked product.

An important factor in rounding which requires close control is the amount of dusting flour used. An excessive amount of dusting flour in the rounder will result in streaks in the baked loaves. Also, it will interfere with the proper sealing of the rounded pieces which, as a consequence, may open up on proofing. The over-all effect will be bread which is unsymmetrical in form and lacking in general appearance. Hence the dusting flour should be reduced to the absolute minimum consistent with proper performance of the rounder. The practice of waxing the rounding surface of the unit, permitting thereby the complete elimination of the use of dusting flour, is recommended as a step in the right direction.

In hand shops the rounding operation is, of course, performed by hand. This is accomplished by a rolling motion applied to the dough piece with a downward pressure along the edges of the piece. Here also the controlled use of dusting flour is of the utmost importance.

INTERMEDIATE OR OVERHEAD PROOF

The rounded dough balls are next subjected to a brief period of 8 to 12 minutes of fermentation during what is variously called the short proof, first proof, preliminary, intermediate or overhead proof. Actually, of course, fermentation continues uninterruptedly in the dough through all its stages of manipulation from the mixer onward. However, as the dough is subjected to dividing and rounding, much of the carbon dioxide gas formed in the dough is forced out so that the dough in a great measure loses its pliable character and becomes too sensitive to any further stresses that develop during the subsequent moulding operation. Doughs which are moulded immediately after rounding lack the necessary extensibility and tear easily, exposing raw dough surfaces with their pronounced stickiness. The short preliminary proof is merely a rest period which permits the individual dough pieces to again become sufficiently aerated so that they will process properly during the moulding operation.

For the purpose of this preliminary proof, the dough pieces are placed either into special floor cabinets, known as intermediate proofers and used principally with small doughs, or they are conveyed by means of a continuously moving conveyor equipped with special canvas dough pockets, cups or trays through an overhead cabinet, known as an overhead proofer and designed for large plants. In the overhead proofer the speed of the

conveyor mechanism can be regulated and the proof time closely adjusted to the requirements of different doughs. Regardless of which type of proofer is employed, some means for the control of temperature and humidity within the cabinets should be provided. Proper humidity control is of especial importance, with a relative humidity of 70 to 75 percent being the generally accepted optimum range. If an atmosphere within the proofer is much drier, there exists a definite danger of crust forma-

FIG. 79—Automatic intermediary proofer of the overhead type. (*Baker Perkins Inc.*)

tion on the dough pieces which will result in the appearance of hard curls and streaks in the crumb of the baked loaf. A dried dough skin also tends to break during the moulding operation and thereby contributes to difficulties during that stage. If, on the other hand, the humidity within the proofer is higher than the indicated optimum, moisture absorption by the dough surface may occur. This is equally undesirable as it leads to sticky doughs and difficulties at the moulder, necessitating the use of excessive amounts of dusting flour which, in turn, impairs the physical appearance of the baked crumb. Proper temperature control is also important. Temperatures within a range of 80° to 85° F. will generally be found to be most suitable. Excessively high temperatures cause too rapid aging, a diminution of the dough's gas holding capacity, and, especially when associated with high humidities, a tendency toward the development of stickiness. Too low temperatures chill the dough pieces,

bringing about a retardation of the fermentation rate and hence an undue extension of the proof time. It is also vitally important to protect the proofing doughs from drafts which not only promote crusting of the surface but are also one of the major causes of non-uniformity in the final bread character.

MOULDING

After the dough pieces have passed through the intermediate proof, they are shaped or moulded into the form of a loaf prior to being placed in the baking pans. The moulding operation, now performed almost exclusively by moulding machines, involves three distinct phases. The first, performed by two or more sets of closely spaced rolls, flattens or sheets the dough piece into a thin, oval shaped dough sheet. During this operation, the dough is largely de-gassed and the gas cells undergo considerable division and uniform distribution throughout the piece. The sheeted dough then enters the curling section where it is curled or rolled into a cylindrical shape. Finally, the curled dough is subjected to a rolling pressure which seals the seam of the loaf. During recent years a number of modifications of the conventional moulding procedure have been introduced, such as reversed sheeting, loose curl moulding and cross-grain moulding, in an effort to improve the crumb and general loaf characteristics of the baked loaf. These modern innovations in moulding have been discussed by Mohr (*29*) and Hunter (*30*).

The two principal requisites of satisfactory moulding are the condition of the dough being moulded and the setting of the moulder. Errors committed in either phase result in defects in the moulded piece which then carry through to the finished product. The ideal dough for moulding is dry, soft and extensible. The factors involved in obtaining such a dough may be traced back to the raw flour. Thus if flour in the sweating stage is mixed and fermented, it will cause its first difficulty during the moulding operation. Improperly mixed doughs also react unsatisfactorily, over-mixing tending to yield doughs that spread excessively when being sheeted, while undermixed doughs exhibit bucky characteristics. Defective moulding is also encountered with sticky doughs that result either from the excessive use of malt of improper humidity conditions during the intermediate proof. One of the principal complaints, however, stems from the misuse of dusting flour in the rounding and proofing operations. Doughs which have been dusted too heavily tend to acquire a thick, tough skin that resists the action of the sheeting rolls so that the skin is torn as the piece passes through the head rolls. Furthermore, such a skin lacks adequate adhesive property which may cause the moulded piece to uncurl during subsequent proofing and baking, resulting in deformed,

unsaleable loaves. Also, excessively thick dough skins eventually show up in the finished product as unsightly streaks in the crumb.

Given a dough with optimum characteristics, the second requirement for satisfactory moulding is the proper setting and operation of the moulder. The general practice is to set the sheeting rolls as close as is practicable to obtain the greatest degree of gas cell dispersion and thereby create the condition for a fine, even grain in the finished loaf. While the objective aimed at is desirable, the sheeting rolls are frequently set too tight with the result that the skin of the dough pieces is torn, thereby exposing the sticky interior with subsequent "gumming up" of the machine. There is also the tendency toward uneven sheeting, the dough sheet being thicker at the side ends than in the center so that the moulded loaf assumes a dumbbell shape. If such a moulded piece is cut lengthwise with a sharp knife, it will be observed that both the cell distribution and cell size are uneven throughout the length of the piece. The other extreme, i.e., head rolls that are set too loose, falls short of the ideal by failing to achieve adequate degassing on the one hand, and uniform cell dispersion on the other. The general result in the finished loaf is a coarse grain structure and the frequent occurrence of large holes. An excessively loose setting of the head rolls also fails to sheet the dough thin enough to permit the formation of a sufficient number of curls which also impairs uniformity of the baked bread. Practical experience has shown that about two and a half curls constitute the correct extent of curling.

It is good practice to adjust the setting of the head rolls to the requirements of each individual batch of dough, aside from the obvious adjustment needed by varying sizes of the dough pieces being moulded. Thus an 18-ounce dough piece will require a closer setting of the head rolls than will a 23-ounce dough piece. Slack doughs call for a more open adjustment of the sheeting rolls than do stiffer doughs. The same holds true of sponge doughs as compared with straight doughs. Whether or not the rolls are set too tight for a given dough can usually be judged by examining closely the surface of the moulded pieces which exhibit a perceptible roughness when the sheeting rolls are set too close.

The performance of the sheeting rolls is influenced to a considerable degree by the manner in which the dough pieces are fed into the moulder hopper. The problem of improper feeding usually arises only with automatic equipment since there is no difficulty with hand feeding to so insert the dough piece into the hopper that its thin edge contacts the rolls first. In automatic equipment in which the proofed dough pieces are fed directly by the overhead proofer to the moulder hopper by means of a connecting chute, improper design may cause the dough to roll or tumble rather than slide into the head rolls. In that case very frequently the

broad side of the dough contacts the rolls first, making it difficult for the rolls to take immediate hold of them. This condition will not only lead to doubles, but will also result in the sudden application of excessive pressure on the dough piece once it begins to pass between the rolls, subjecting it to more severe punishment than is desirable for best results.

Of equal importance to correct moulder operation is the proper setting of the pressure board or of the compression plate to the drum. The setting must be sufficiently close to ensure adequate sealing of the seam that results from the curling operation and to yield a dough loaf of uniform cylindrical shape. When the compression plate is set too loose, the dough loaf will have an oval shape, being thicker in the center than at the ends. When baked, such pieces tend to open up and result in misshaped loaves. If, on the other hand, the compression plate is set too close to the drum, the moulded loaves assume a dumbbell shape, which also leads to non-uniform baked loaves.

In moulding, as in all other make-up operations, it is again desirable to limit the use of dusting flour to an absolute minimum. Whenever doughs process satisfactorily it will be found preferable to restrict the use of dusting flour to the kneading operation in the drum, adjusting the amount applied to the condition of the doughs emerging from the moulder. In other words, if the moulded pieces show stickiness, slight dusting is indicated. The excessive use of dusting flour at the head rolls will usually give rise to streaks and uneven color in the crumb, while indiscriminate dusting at the drum interferes with proper sealing of the loaf and may result in a baked loaf having a dull, floury appearing crust. While a certain amount of dusting during dough make-up is generally required and desirable, the aim should always be to keep the amount of dusting flour, starch or any other material used to less than 1 percent of the dough weight out of the divider. When used at that level, the dusting material will not result in defects in the finished product.

PANNING

The moulded dough pieces are immediately placed into baking pans on their emergence from the moulder. While the panning operation is still largely performed by hand, with an operator picking up the moulded pieces from the discharge apron of the moulder and depositing them into pans, specialized panning equipment, coupled onto the moulder and synchronized with it, has recently been developed for large volume production. Correct panning operation calls for a number of precautions. Thus it is good practice to have available an accurate and sensitive scale at the discharge end of the moulder with which the weight of non-uniform dough pieces can be checked. Even under normal moulding conditions it

occasionally happens that two dough pieces are moulded together, yielding a single dough loaf of double weight. On the other hand, dough sheets may at times break and produce two dough pieces of less than the required weight. When such cases are encountered, the off-weight doughs should not again be remoulded immediately. It is generally preferable to return such dough pieces to the mixing room for incorporation into new doughs. When this is not possible, the dough pieces should be given a brief rest for recovery, hand scaled and then remoulded. It should be clearly understood, however, that with this latter procedure, it is quite impossible to avoid some diminution in quality of the remoulded doughs.

Panning should be so carried out that the seam of the dough is placed on the bottom of the pan. This precaution is required to prevent subsequent opening of the seam during proofing and baking and the later appearance of rough and irregular crust surfaces. Prior to the actual panning, the pans themselves must be properly conditioned. This involves reducing the temperature of the pans to that prevailing in the room, and treating their interior surface in such manner that they will readily release the baked loaf. When excessively warm or cold pans are used for panning, irregular proofing results.

Pans from which bread has been dumped have a temperature of about 270° F. which must be reduced to about 90° F. Depending upon cooling conditions, the time required for this temperature reduction may vary anywhere from 6 minutes to as long as 2½ hours. Undoubtedly the most rapid procedure is to cool the pans by means of forced air circulation while they are being conveyed on a hooded conveyor from the bread depanning station to the greasing machine or moulder discharge end. The most efficient of such pan conveying and cooling systems will reduce the pan temperature to about 90° F. in some 4½ to 5 minutes. A second method of pan cooling is to place them upon an open conveyor of the wire mesh or steel slat type. Under these conditions cooling to 90° F. will require approximately 12 to 15 minutes. The most common procedure followed in the vast majority of plants is to stack the hot pans on specially designed pan trucks and let them cool at ordinary room temperature, which may vary from 75° to 95° F. Pan cooling times with this method range from 1½ to 2½ hours, although the time may be reduced considerably by playing an air fan on the pans. The installation of pan conveying and cooling systems is limited to plants with high production and sufficient lineal length between the pan dumping and refilling points to provide for 6 minutes cooling time. The most obvious advantages of such systems are the saving in labor cost made possible by their automatic features and also the reduction in necessary capital investment in pans. The more quickly pans are cooled, the more frequently they can

be re-used and consequently the fewer sets are required for a given production volume. The pan requirements of an average bakery are generally determined on the basis of the pan capacity of the plant's ovens. For each set of pans in an oven, there are required two sets for use in the proof box and three to five sets for the cooling, greasing and panning operations.

Surface treatment of the pans may be one of two types, namely, greasing before each panning operation, or applying a more permanent silicone coating which will withstand a hundred or more bakings before requiring a renewal of the coating. Pan greasing may be done either by hand or by automatic or semi-automatic machines. The advantages of mechanical pan greasing are that the operation can be performed at a faster rate, applies a more uniform layer of grease to the pan surface, and is more economical with respect to the amount of greasing material used. Pan greasing machines are available in several designs, including units which require feeding of the pans by hand and such where pan conveying is automatic and synchronized with the oil spraying mechanism. Various types of oils are used for this purpose, although for hand greasing lard has been found to be preferable to most other shortenings. Mineral oil is possibly the least desirable because of its tendency to produce excessive smoking in the oven and also because it possesses no nutritive value. The amount of grease used should be closely controlled to avoid overgreasing on the one hand, which produces a frying effect during baking and cave-ins at the sides in Pullman type bread or when covered pans are used, and insufficient greasing on the other hand, since this causes sticking of the baked loaves in the pan. Under good production conditions, 0.1 to 0.2 percent of greasing material, based on dough weight from the divider, has been found to yield the most desirable results.

Pans may also be coated more permanently by special silicone resins developed specifically for this purpose. Silicones are synthetic materials of a semi-organic nature consisting of the inorganic element silicon combined with organic hydrocarbon groups. Depending upon the amount and kind of organic groups reacted with silicon, silicones can be produced in any of five physical forms—resins, greases, fluids, compounds and rubber. All of the silicones have excellent heat stability, inertness and electrical non-conductivity, water-proofness, water repellency and ease of handling. While silicone oils and greases have been adopted to some extent as high temperature lubricants by the baking industry, the most extensive use of silicones in baking has been as a pan coating material. The pans, prior to being coated by silicones dissolved in an appropriate organic solvent, are thoroughly cleaned of adhering fat and charred residues, or if new they are first burned out. The silicone coating may be

applied either by a spraying or a dipping procedure. The coated pans are permitted to air-dry until the coating has lost its tackiness and are then cured in the bake oven at temperatures ranging from 400° to 425° F. for periods of 4 to 6 hours. Care must be taken not to exceed a curing temperature of 425° F. with tinned pans as the melting point of tin is 449° F. A properly coated pan will give effective service for 100 to 200 bakes. Pans may be recoated a number of times before it becomes necessary to remove completely the old coating by means of a solvent. Culbertson and Sheeran (*31*) have outlined the proper procedures for preparing, coating and curing of various types of baking pans. The adherence and useful life of silicone coatings are governed to a considerable extent by the application procedure which requires some expertness.

An essential factor in bread quality is the relationship between the size of the pan and the volume of dough deposited in it. Pans which are either too large or too small for the amount of dough used will produce bread with various defects, such as coarse uneven grain, small volume, unsatisfactory break or shred, etc. A careful study of the factors involved has shown that for round top bread the ratio of 5.8 to 6 cubic inches of pan volume for each ounce of dough yields best results. In the case of Pullman bread, a pan volume of 6 cubic inches per ounce of dough for a closely grained loaf, and of 7 cubic inches per ounce of dough for a more open, spongy loaf, are generally accepted as average values. The volume content of a pan is obtained by multiplying the width of the pan bottom by its length and multiplying the sum obtained by the depth of the pan as measured vertically at the center of the pan. Since, however, bread pans normally have an outward flare of 1/4 to 3/8 inches, the actual volume of the pan is greater than obtained by the above calculation. This may be corrected for by dividing the volume obtained by the factor 0.87. The flare of the pan performs several useful functions, the principal one of which is the prevention of cave-ins of the sides of the loaf when the loaf shrinks during bread cooling. It also prevents the occurrence of squat loaves that may cause difficulties during the wrapping operation and facilitates the nesting of one pan in the other, thereby affording a more convenient, space-saving storage of the pan equipment.

Several methods of bread panning have been developed in the course of years, all of which have as their principal aim the development of a uniformly close and even grain and a soft silky texture. The two most widely accepted variations are cross-panning and twisting. In cross-panning the moulded dough piece is cut transversely into three or four pieces which are then placed into the pan at right angle to the long sides of the pan. In twisting the dough loaves represent half-weight units of normal length, of which two are then combined into a single unit by giv-

ing them two or three twists. The twisted dough piece is then deposited in the pan.

FINAL PROOFING

A dough piece which has passed through a moulding machine will be found to possess little "life." This is understandable in view of the rather severe punishment it has received during sheeting, curling and compression. The over-all effect of these operations is to yield a dough from which the greater portion of gas has been knocked out and the gluten rendered bucky. If such a piece were to be baked immediately, an ex-

FIG. 80—Progressive stages of loaf aeration: (left to right) at start of proofing, fully proofed loaf, and baked loaf. (*Wheat Flour Institute.*)

tremely small, heavy loaf with coarse grain and texture and a shell top would be obtained. Before a large, well-risen loaf can result, the dough piece must be allowed to recover some of its lost desirable characteristics, i.e., it must be permitted to aerate again and to impart mellowness and extensibility to its gluten. The purpose of the final proof is to facilitate this recovery of the moulded loaf.

Improper proofing is generally credited with being one of the principal sources of bread faults. Since it represents the next to the last stage in bread production, errors committed at this point can no longer be rectified. Such undesirable conditions as tough crusts, poor volume, coarse uneven grain, rough texture, absence of true bread flavor, unsatisfactory color, and shell tops may all arise as a result of improper final proofing. Regardless of the excellent quality of materials used, or of the care and control exercised during the preceding stages of dough making, the in-

expert conduct of the proofing operation will largely nullify previous efforts and result in bread of mediocre quality. Hence the need for the strictest attention to all details of the proofing process cannot be overemphasized.

In actual practice, the pans containing the dough are placed on movable racks which are then wheeled into proof boxes or, as they are sometimes called, steam boxes. These are relatively large chambers, accom-

FIG. 81—Dough receiving final proof

modating a fair number of racks, built of metal or metal-lined wood panels and well insulated. Provision is made for both temperature and humidity control since these conditions are of the utmost importance to successful proofing. The general recommendation is that the temperature be maintained at a constant level of 95° to 98° F. and the relative humidity at 80 to 85 percent. At this temperature the fermentative action within the dough proceeds at nearly maximum rate, causing the dough to rise rapidly to the desired level which should be at least double the volume of the dough piece when panned. By maintaining the relative humidity at the indicated level the surface of the dough is prevented from crusting.

Proof boxes which are maintained at much higher temperatures than the ideal range of 95° to 98° F. lead to loss of flavor and poor keeping

quality in the finished product. There generally also results an irregular fermentation since there exists a definite heat gradient from the outer portion of the dough piece into its interior. Thus a temperature of over 100° F. may prevail in the outer portion of the dough, whereas the center may register only 85° F. The result is that fermentation will proceed much more vigorously in the higher temperature zone than in the central section, giving rise in the finished loaf to a fine-textured outer rim and a coarse center. On the other hand, proof boxes maintained at too low a temperature result in long proofing times and over-all coarseness in the bread.

Low proof box humidity is another frequently encountered factor that has an adverse effect on bread quality. By promoting the formation of a crust on the proofed dough, it prevents optimum expansion in the oven and thereby causes low volume bread and shell tops. Surface dryness also inhibits the amylolytic enzymes in that region so that sugar and dextrine production is reduced. This in turn has an unfavorable effect upon color formation in the crust during the baking process. If, on the other hand, the humidity in the proof box is kept too high, the dough surface becomes too moist which leads to a tough crust and blisters in the bread.

Under some conditions somewhat lower than normal proof box humidities, e.g., adjusted downward to about 80 percent, are found to be desirable. Thus when doughs containing some 6 percent of milk solids are proofed, the lower humidity will prevent a subsequent development of toughness in the bread crust. Another such case exists when somewhat lower proofing temperatures are used. The same holds true also with over-aged doughs which tend toward excessive dextrinization in a moist box, resulting in extremely brittle crusts.

The third important controlling factor is the proof time. The general aim should be to keep the time fairly short, since a short proofing period is conducive to superior grain. Generally speaking, a proofing time of 45 minutes will be found ideal, although a range of from 30 to 60 minutes is considered satisfactory in practice, depending upon the temperature maintained. The correct proofing time can be established only by practical experimentation within a plant, taking into account the over-all conditions that prevail in the plant. Over-proofing is recognized by loaves possessing pale crust color, coarse grain, poor texture, unsatisfactory keeping quality and undesirable flavor caused by excessive acid development. In the case of green or weak flours it also results in poor loaf volume brought about by a collapse in the oven. Under-proofing, on the other hand, produces small volume, shell tops, a foxy red crust and occasional bursting at the sides.

Correct proofing must also take into account to some extent the pre-

vailing oven conditions. If a cool oven is used, shorter proofing times will generally yield better results, while with fairly hot ovens a longer proof is more desirable. If the aim is to have a good oven spring, or bread with a break and shred, and a hot oven is used, then the doughs should be proofed until they fill out the pans completely and extend slightly above the pan top. This applies only to pans with a depth of 2½ to 2¾ inches. With pans of greater depths, such as 3 to 3¼ inches, and using the same dough weight per unit volume, break or shred may have to be sacrificed if over-proofing is to be avoided. The correct height of proof must generally be determined for each individual plant, selecting the height that yields the best result in bread characteristics. It is generally recommended in the interest of bread uniformity to proof to a predetermined standard height rather than for a given time. Proofing to height automatically compensates for variations in proof box conditions that are difficult to control. Thus, conditions may not be absolutely the same throughout the box. Also it is very difficult to maintain identical temperature and humidity conditions from day to day. If a definite proof time is adopted, these variations in conditions will be reflected in non-uniformity of the bread from day to day and even from bake to bake. By proofing to height such variables are largely eliminated and greater uniformity is obtained.

Freilich (*32*) has recently studied the effects of extreme variations in the time, temperature and humidity factors in dough proofing on the quality characteristics of the bread obtained. The results are highly interesting and supply convincing confirmation of the limits of time, temperature and humidity established by good baking practice. The effects of proof time were studied by varying the time from 0 to 150 minutes using 450 g. (1 lb.) doughs. The proof temperature employed was 104° F. The results are reproduced in Table 106.

TABLE 106. EFFECTS OF PROOF TIME ON LOAF VOLUME, pH OF BREAD, AND LOSS OF WEIGHT IN BAKING

Proof time (min.)	Volume per lb. of bread (ml.)	pH of bread	Loss in baking (g)
0	1,270	5.49	46
15	1,610	5.46	52
30	1,980	5.41	61
45	2,310	5.40	69
60	2,640	5.34	72
75	2,780	5.31	73
90	3,030	5.26	80
120	3,550	5.16	88
150	4,090	5.13	89

The tabulated values reveal the tremendous spread in loaf volume that is obtained with pronounced differences in proof time, the range in volume being from 1270 ml. with a 0 minute proof time to 4090 ml. with a 150 minute proof time. This volume difference is visually underscored by Figure 82.

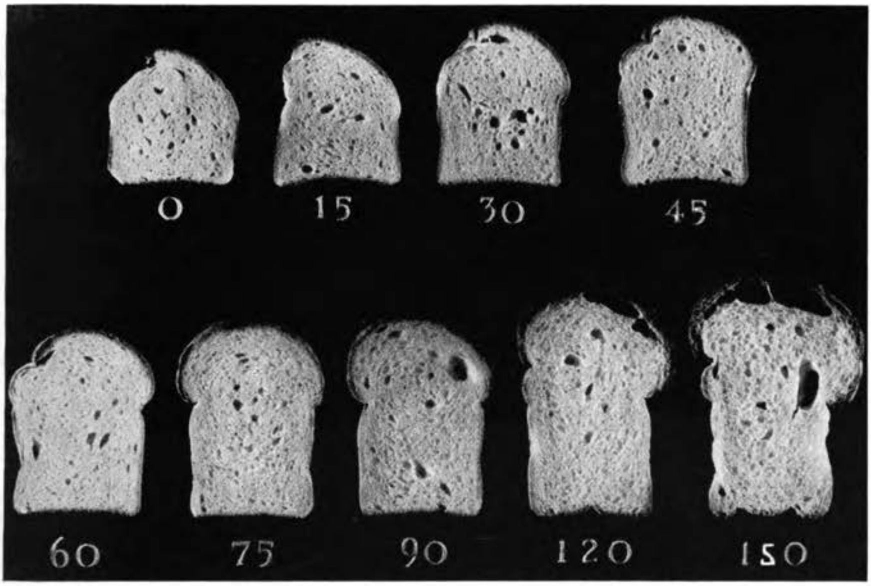


Fig. 82—Photographs of loaves obtained from 450 g. doughs, proofed from 0 to 150 minutes; number under each loaf indicates proof time.

The spread in texture and grain, and in bread quality, was comparable to the spread in loaf volume. The 0 and 15 minute proof loaves were compact and heavy, with the 30 minute proof loaf showing considerable improvement but being still on the heavy side. Loaves obtained with 45 and 60 minute proof times were normal in texture and grain, with the 60 minute loaf possessing the greater tenderness. The 75 and 90 minute proof loaves showed a rather open grain, though they were still acceptable. The loaves obtained with longer proof times showed large cells, a very open grain, and poor keeping quality. There was a tendency to shell tops with the shorter proof times, but the longer proofs produced smooth breaks on the bread. There was a progressive reduction in pH values from 5.49 to 5.13 with time of proofing, indicating a progressively increasing acidity in the dough. The baking loss increased with longer proof times, corresponding to the expansion of the dough surface with continued proofing.

The effect of proof temperatures were studied by varying temperatures

from 56° to 135° F. and proofing to constant volume. The results are tabulated in Table 107 and shown graphically in Figure 83.

TABLE 107. EFFECTS OF TEMPERATURE DURING PROOFING ON PROOF TIME AND LOAF VOLUME

Loaf No.	Proof Temperature (° F.)	Proof Time (min.)	Volume per lb. of Bread (ml.)
1	56	270	2,160
2	70	102	2,200
3	86	60	2,280
4	95	50	2,270
5	104	47	2,290
6	115	41	2,260
7	125	37	2,210
8	135	36	2,110

Loaf volume and bread quality varied within a relatively narrow range; the volume range was from 2100 ml. for the dough proofed at 135° F. to 2290 ml. for the dough proofed at 104° F.; the range of temperature for optimum loaf volume was 86° to 115° F.; 86° F. is somewhat

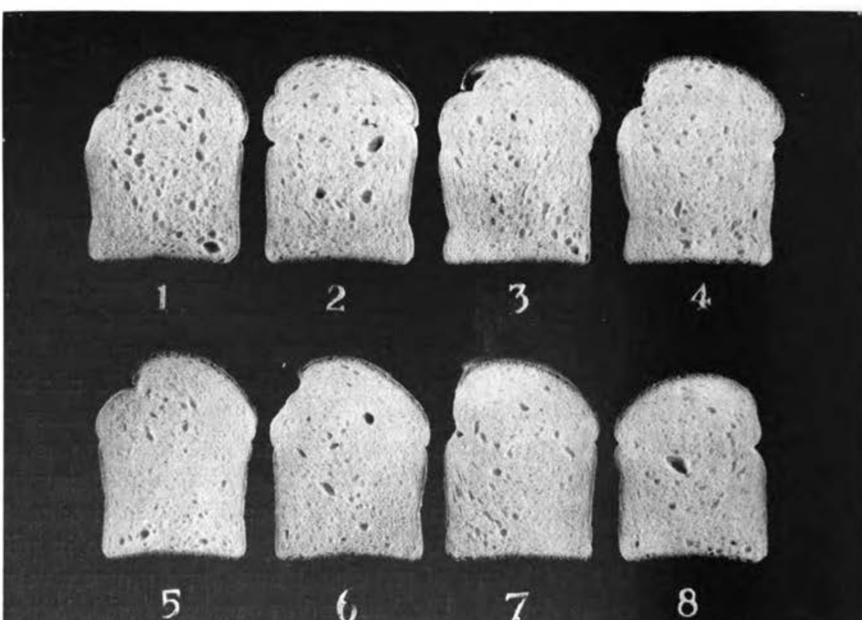


FIG. 83—Photographs of loaves obtained when proofing at different temperatures; numbers under each loaf correspond to loaf number in Table 107.

lower, and 115° F. considerably higher than the proof temperatures commonly used in the industry. The loaves proofed at 56° and 70° F. were slightly more open than normal and appeared to have a different type of cell structure. The doughs proofed at 86°, 95°, 104° and 115° F. produced bread of normal appearance, texture and grain. The dough proofed at 125° and 135° F. produced bread of about normal texture and grain, but the sides of the loaves were smoother and the corners sharper than normal, indicating a softening at the points of contact with the pans, due possibly to starch gelatinization, proteolytic activity, or a combination of both. The greatest effects of temperature during proofing were shown by proof times; these values ranged from 270 minutes for the lowest temperature to 36 minutes for the highest temperature. These proof temperature experiments indicated that the range for normal volume and quality is 86° to 115° F., and is wider than that normally used in practice; in this range the spread in proof time is about 20 minutes, so that proof time is not a limiting factor if a baker finds it desirable to proof at any temperature within the satisfactory range.

In studying the effects of humidity, this factor was varied from a low of 35% to a high of 90% relative humidity. All doughs were proofed at 100° to 104° F. The results of the humidity experiments are shown in Table 108.

TABLE 108. EFFECTS OF HUMIDITY DURING PROOFING ON PROOF TIME, LOAF VOLUME AND YIELD

Loaf No.	Relative Humidity (%)	Proof Time (min.)	Loss in Proofing and Baking (g)	Volume per lb. of Bread
1	35	57	74	2,230
2	50	52	72	2,320
3	60	54	71	2,230
4	80	49	64	2,150
5	90	46	64	2,270

Variations in humidity had no significant effects on volume, texture or grain. There were, however, significant differences in the appearance and color of the crust; the loaves proofed at the lower humidities had lighter, duller, more spotted crusts, while those proofed at the higher humidities were darker in color and had more uniform, cleaner looking crusts. Variations in humidity also produced differences in proof time and in bread yield. The doughs proofed at the lower humidities fermented more slowly than those at 80 and 90 percent humidity. The

yield of bread was greater at the higher humidities, obviously because of reduced losses by evaporation in the proof box at the higher humidities. The humidity experiments indicated a relatively narrow range of 80 to 90 percent within which the best results might be obtained. This conforms to the values found best in baking practice.

CHAPTER XVIII

THE BAKING PROCESS

The actual baking process is the last and at the same time the most important step in the production of bread. Through the agency of heat an unpalatable dough mass is transformed into a light, porous, readily digestible and highly appetizing product. The changes involved in this conversion are complex and fundamental. The biological activities that take place in the dough are arrested, the responsible microorganisms and enzyme systems are destroyed, a rather unstable colloidal system is far-reachingly stabilized, and the basic properties of starch and gluten are drastically altered. At the same time new substances, such as caramelized sugars, pyrodextrins, melanoidins and various flavor substances are formed that endow the baked product with certain desirable organoleptic properties.

All of the reactions involved in the transformation of dough into bread must occur in their proper sequence and under controlled conditions. The amount of heat supplied, the humidity within the baking chamber, and the time of baking are all factors that exert a fundamental influence on the general character of the baked bread. While many of the actual chemical and physical reactions that take place in a baking dough are not as yet fully understood, research within recent years has greatly expanded our insight into baking reactions. Because of the importance of the baking process, it is desirable to review in some detail our present concepts as they pertain to this phase of bread production.

BAKING REACTIONS

When dough is placed in the oven, it is first met by the hot atmosphere of the baking chamber which causes an almost instantaneous formation of an observable film on the dough surface. Depending upon the prevailing moisture conditions in the oven, this film will be more or less expandable. The next important reaction is the so-called oven spring, or rapid expansion of the dough's volume by about one-third of its original size. This oven spring, while due to the immediate effect of heat penetration, is caused by a complex of several factors. A purely physical effect of heat upon a gas is to cause an increase in its pressure. If such a gas is confined in an elastic container, the visible effect is an expansion

of the container. A dough piece contains millions of minute cells in which the gas, under the influence of heat, begins to increase in pressure and causes the expansion of the confining cells. Another purely physical effect of heat is to reduce the solubility of gases. A considerable proportion of the carbon dioxide present in the dough is in a state of solution in the dough liquid. Hence as the temperature of the dough liquid rises to about 120° F., the carbon dioxide held in solution is liberated. This freed gas adds its share to the already existing gas pressure, causing further expansion of the gas cells and a corresponding expansion of the dough piece as a whole. A third physical effect of heat is to change liquids of low boiling point into gases by the familiar process of evaporation. Alcohol constitutes quantitatively the most important liquid in dough which evaporates at a relatively low temperature so that it is transformed into vapor during the baking process. This evaporation of alcohol at about 175° F. in turn increases the gas pressure leading to an additional expansion of the gas cells. In addition to these three purely physical effects of heat, there is the added effect upon the rate of yeast metabolism. One of the principal factors governing the rate of yeast fermentation, and hence of carbon dioxide and alcohol formation, is temperature, the rate increasing with increasing temperatures. Thus, until the thermal deathpoint of yeast is reached at an approximate temperature of 140° F. the yeast in the dough will generate carbon dioxide at an increasingly accelerated rate which is of sufficient magnitude to constitute a perceptible contributing factor to volume expansion. Yeast fermentation is aided at the elevated temperatures by an increased diastatic activity, with both the beta- and alpha-amylases being markedly activated. Oven spring is further facilitated by a pronounced softening of the dough which sets in at this initial stage.

This softening process is quickly counteracted by the starch swelling which is initiated at a temperature of about 130° F. Starch swelling is accompanied by a transfer of water from other dough ingredients to the starch granules. This has two primary effects. The starch granules increase greatly in size and assume a more fixed position in the gluten network. Also, since part of the water required by the starch for swelling is removed from the gluten, the strands and fibers are strengthened and become more viscous and elastic. Although the major extent of starch swelling occurs over a relatively short range of temperature rise, some further swelling may occur during the continued heating of the dough. The degree to which starch gelatinizes is largely governed by the conditioning it has received from alpha-amylase during fermentation and during the initial stage of baking. In properly diastated doughs, the viscosity of the starch will be of just the right degree to permit the expan-

sion of the dough on the one hand, and to provide the supporting framework for the loaf on the other. While in the fermenting dough the gluten network supplies the structural support, this no longer holds true at the intermediate temperatures of baking which have a tendency to soften and liquefy the gluten. It is here that starch assumes the role of maintaining the volume of the dough. A dough which has been insufficiently diastated and in which, as a result, the starch has been inadequately dextrinized will yield a starch gel which is too rigid to permit optimum expansion. Such a condition leads to unsatisfactory loaf volume and texture, a condition which is characteristic of under-diastated flours. On the other hand, if a flour is over-diastated or if too much malt supplement is added to a dough, excessive starch dextrinization occurs which will reduce the viscosity of the starch gel to a point where it is unable to withstand the increased gas pressure. Individual gas cells will coalesce to form larger cells and there will be loss of volume because of escape of gases. Also, since the color of dextrines is perceptibly darker than that of starch, crumb color will also suffer. These are the characteristics that mark bread made from over-diastated flour or dough. While diastatic supplementation plays a role in fermentation, its principal effect comes to the fore during the actual baking process as is indicated by the unsatisfactory quality of bread which results from improper malt supplementation.

In addition to starch gelatinization, there are also far-reaching modifications in the nature of the gluten network as the temperature of the dough increases. Heat at first has a liquefying effect upon the gluten which therefore relinquishes its role as the structural support of the dough to the gelatinizing starch. Starch in order to form a gel requires more moisture than is available in the form of dough liquid and hence begins to draw upon the gluten for additional moisture. This has a dehydrating effect upon the gluten. Gluten coagulation sets in at about 165° F. and continues slowly until the end of baking. There is also a progressive stretching of the gluten strands with dough expansion. This is caused by the increase in gas pressure mentioned above. This pressure does not increase uniformly with rising temperature. There is a marked drop in pressure in the temperature range in which starch swelling occurs and also at the end of the baking period. During these fluctuations in pressure, the oven spring continues upward at a fairly uniform rate and there is no perceptible corresponding decline in loaf expansion during the low pressure period. The suggested explanation for this is that at the temperature at which a drop in pressure occurs many of the minute gas bubbles or cells coalesce to form fewer and larger gas bubbles, thereby releasing the stress upon the surrounding dough film, this release of the stress being accompanied by a drop in pressure. Doughs made from

green flours, which are inadequately oxidized, possess a relatively weak gluten structure so that their gas cells tend to coalesce to a greater extent, with the result that the bread will show an uneven grain with relatively large air cells. With such flours the pressure drop is quite pronounced. Properly oxidized flours, on the other hand, possess a stronger gluten which is able to withstand the rising pressure more effectively and without much collapse of gas cells, and such flours yield bread with fine, elongated cells and matured texture.

Aside from flour maturity, the treatment which the flour receives during the various stages of baking also exerts an important influence upon the appearance and nature of the cell structure obtained in the final loaf. Thus Garnatz (*33*) has listed the following factors as being primarily influential in determining the type of cell structure: Extent of fermentation, rate of fermentation, mixing, moulding, pan size, proofing, baking, and slicing. The more specific effects of each of these factors are as follows:

An under-fermented or "young" dough tends to yield a heavy-walled, coarse cell structure, with irregular cell size and large holes or cells. Over-fermented or "old" doughs generally yield cells which are thin-walled, weak or crumbly, round in shape and only moderately open, giving the overall impression of stagnancy.

Too rapid a rate of fermentation in doughs coming to the moulder makes it difficult for this unit to effectively degas the dough pieces and this results in an irregular cell structure and large holes. Rapid fermentation of the dough entering the oven usually results in a type of cell structure described as "young." An excessively slow rate of fermentation at this stage produces a stagnant type of cell structure, designated as "old."

Undermixing of the dough may cause a cell structure having the general characteristics obtained with young doughs. Overmixing may yield a similar cell structure except for the absence of many large holes. The cells will be round, heavy-walled, somewhat open, but fairly uniform in size.

It has been shown that the origin of the cell is the gas bubble within the dough mass. A thorough, uniform dispersion of minute gas bubbles is essential to an ideal cell structure. The proper adjustment of the moulder contributes importantly to the attainment of this end.

The ratio of pan size to scaling weight materially affects cell structure. The smaller the cubic displacement of the pan in relation to the scaling weight of dough, the easier it is to attain a fine, uniform cell structure. The reverse also holds true because of the tendency to overproof in order to obtain an adequate filling out of the pan.

Pan proof is a critical stage in cell structure development. Overproof-

ing in an effort to obtain large volume results in an open grain with round cells which reflect an "old" condition. On the other hand, too short a proof causes the grain to assume "young" characteristics.

Proper rate of baking is also of importance. Too rapid a bake should be guarded against since the premature formation of a strong crust arrests expansion and the forces created by heat in the interior of the loaf play havoc with the cell structure, causing disruption and coalescence of cells and resulting in a heavy-walled, coarse, open and irregular structure.

Finally, correct slicing conditions are required to preserve the original cell structure of the loaf. Dull blades, or slicing bread when it is too warm, result in a coarseness and type of crumbliness that detract materially from the appearance of the slice.

Garnatz defines an ideal cell structure as one in which the cells "are small, fairly thin-walled, slightly elongated, uniform in size, free from large holes and possessing a smooth, soft, velvety feel when touched lightly with the tip of the fingers."

Baker and Mize (*39*) have studied the reactions which occur during the baking of a dough in which the dough is heated internally by dielectric means and yields a crustless loaf. They observed that when a fermented dough is heated at a uniform heat input, the temperature rise within the dough is not constant but varies slightly as different temperature levels are attained, indicating increased heat absorption at those levels. Thus there occurs a slight decrease in the rate of temperature elevation during the initial stage of baking until a temperature of about 120° F. is reached. The increased heat absorption at this stage is believed to be due to carbon dioxide coming out of solution in the dough. The temperature then rises uniformly until about 130 to 136° F. is reached, when starch swelling occurs, which again reduces slightly the rate of temperature increase. Thereafter there is a uniform temperature rise until about 175° F., when further heat absorption takes place which becomes progressively more pronounced until the end of the heating at 212° F. This final heat absorption is attributed primarily to the evaporation of alcohol and water. The limiting factor to temperature rise toward the end of baking appears to be alcohol which is distilled off and thereby prevents the dough interior from reaching the boiling point of water.

In a continuation of their studies (*34*) the same authors observed the effects of different types of fats. When no fat at all was used, there occurred a drop in pressure during the softening period of the dough and a stoppage of oven spring. The inclusion of liquid oil in the amount of 3 percent did not alter these effects. However, when 3 percent semi-

solid shortening was used, there was no drop in pressure during the dough softening period and no slowing of oven spring. Apparently fat-free doughs and doughs containing liquid oil become porous during the softening period, allowing the expanding gas to escape. Semi-solid shortening, on the other hand, prevents the occurrence of cell-wall porosity so that the escape of gas is minimized and the dough is enabled to continue its expansion until after starch swelling and on into the zone of gluten coagulation.

Baking tests using dielectric heating methods indicate that there is little flavor formed within the crumb of the bread during baking. Crustless bread which is obtained by these procedures has a rather flat, yeasty flavor which greatly resembles that of the original dough. This fact would indicate that bread flavor is formed principally in the crust region of the loaf from whence it penetrates into the crumb and is retained there by absorption. The coloring of the crust at high temperatures is at present attributed to two major reactions, the caramelization of heat-sensitive carbohydrates, and the formation of melanoidins. Starch, dextrines and sugars undergo certain transformations under the influence of heat which not only affect their color but also their taste and flavor. Starch is broken down by heat into highly colored pyro-dextrins. Residual sugars present in the surface layer of the baking dough piece are also transformed or caramelized into brown colored derivatives. Reducing sugars react under the influence of heat with the amino acids to form highly colored, highly flavored melanoidins which are suspected to contribute importantly to the characteristic bread aroma. Thus when the amino acid leucine is permitted to react with glucose in solution, the originally clear solution assumes a brown coloration and the mixture develops an intense baked bread aroma. Different amino acids form melanoidins with different characteristic odors (*35*). Since both sugars and amino acids are present in dough in adequate amounts, the assumption lies close at hand that the melanoidin reaction plays a significant part in crust coloration as well as in the formation of the characteristic aroma of baked bread.

Komm and Lehman (*36*) believe the principal flavoring substances in white bread to be diacetyl and acetoin. While these substances are present in little more than traces they appear to exert a marked physiological effect. They are not involved in the flavor of rye bread in which the principal flavoring agent appears to be hydroxymethylfurfural, a colorless and highly volatile substance. Other substituted furfurals are presumed to be involved in the aroma principle of rye bread. The loss of flavor substances during bread storage has recently been demonstrated by Farber (*37*). This investigator employed a chemical procedure for esti-

mating the content of volatile substances in food products. The procedure involves the aspiration, in a measured volume of purified air, of the volatile constituents which constitute the odorous and flavor substances in a sample into a standard volume of alkaline potassium permanganate solution. The amount of reduction caused by the volatile reducing substances in the potassium permanganate solution is determined iodimetrically and is used as an index of the content of volatile substances in the sample. The content of volatile reducing substances (V.R.S.) found by the author in samples of white bread and rye bread before and after storage for 24 hours at room temperature is shown in the following table. The high content of volatile material in white bread, as compared to rye bread, is of interest. Furthermore, the almost complete loss in volatile reducing substances after a 24-hour exposure to air is also rather striking.

TABLE 109. V.R.S. IN BREAD BEFORE AND AFTER STORAGE AT ROOM TEMPERATURE

1 gram bread aerated dry with 2 cu. ft. air

Sample	Microequivalents V.R.S.	
	Fresh	After 24 hrs.
Rye	113.6	4.6
White A	179.2*	6.3
White B	274.8*	4.4

* 0.25 cu. ft. air used for these.

Farber's work shows quite clearly that not all of the volatile organic acids, aldehydes and esters are driven off by the baking heat, but a certain proportion of volatile substances is retained to add to bread aroma. Their subsequent loss on storage of bread forms part of the over-all phenomenon of staling in which the disappearance of flavor is one of the major changes undergone by bread.

The rate of temperature rise during baking has been determined by Barrackman and Bell (*38*) who employed thermocouples for this purpose which they centered in the respective batters and doughs. Their data on baking-powder biscuit, muffin, cake and bread doughs are given in Table 110.

It is seen that the rate at which the temperature rises during the initial stages of baking is dependent primarily upon the size of the dough piece, although oven temperature, possibly the ingredients added, and the character and shape of the pan are additional factors. Thus the most rapid initial temperature rises occur with the biscuits and muffins, and the slowest with bread. None of the types of products for which data are given in the above table attain internal temperatures over that of boiling

TABLE 110. INTERNAL TEMPERATURE OF BISCUITS, MUFFINS, CAKE AND BREAD DURING BAKING

	Biscuits			Muffins			Cake		Bread	
Baking time (min.)	15			25			30		32	
Oven temp. (° F.)	450			400			365		450	
Baking tin	Sheets, 2⅛″ dia. cutter			2¼-3″ dia. 6-cup			8 × 1½″ layer		1 lb. tinned	
No. replica determinations	9			6			12		5	
	Min.	° C.	° F.	Min.	° C.	° F.	° C.	° F.	° C.	° F.
	0	22	76.1	0	21	69.8	19	66.2	32	89.6
	1	28	92.4	2	34.5	94.1	34	93.2	32.5	90.5
	2	38	100.4	4	38.5	101.3	41.5	106.7	33	91.4
	3	47	116.6	6	46.5	115.7	47.5	117.5	32	89.6
	4	61.5	142.7	8	62	143.6	55	131.0	35	95.0
	5	79.5	175.1	10	80	176.0	63	145.4	39	102.2
	6	92.5	198.5	12	91.5	196.7	72.5	162.5	48	118.4
	7	97.5	207.5	14	97.5	207.5	78.5	173.3	55	131.0
	8	98.5	209.3	16	99.5	211.1	84	183.2	68	154.4
	9	99	210.2	18	100	212.0	87	188.6	77	170.6
	10	99	210.2	20	100	212.0	90	194.0	90	194.0
	11	99	210.2	22	100	212.0	94	201.2	94	201.2
	12	99	210.2	24	100	212.0	96	204.8	97	206.6
	13	99	210.2	26	100	212.0	97.5	207.5	98	208.3
	14	99	210.2	28	—	—	99	210.2	98.5	209.3
	15	99	210.2	30	—	—	99.5	211.1	99	210.2
	—	—	—	32	—	—	100	212.0	99.5	211.1

water. The same authors also measured the temperatures of crusts. They found in general that crusts of baking products rapidly attain a temperature approximating that of boiling water, after which the temperature again rises as dehydration of dough colloids proceeds. There is a slowing down of dehydration during caramelization of the crust, so that in a properly browned crust the temperature does not exceed 150° C. (302° F.).

BAKING CONDITIONS

The conditions of heat and humidity maintained in the oven during the baking process must be adjusted to the varying requirements of the type of product being baked. The normal range of baking temperatures encountered in practice is from 375° to 450° F. The humidity conditions in the baking chamber range from low, due entirely to the evaporative effect of heat upon the moist dough, to high, obtained by the injection of moist steam into the chamber for periods of from a few minutes to as

long as half the baking time with certain types of products. The baking time employed, ranging on an average from 25 to 35 minutes, is controlled primarily by the temperature level, being shorter with high baking temperatures and longer with lower baking temperatures. Thus, as far as the actual baking conditions are concerned, the operator must control time, temperature and humidity, the triumvirate of environmental factors that governs that baking process from beginning to end.

More specifically, ordinary white pan bread of 1 lb. weight requires a baking time of about 30 minutes at a temperature of 425° F. with steam injection for 3 to 4 minutes during the initial stages of baking. With larger loaves the baking time must be extended by a few minutes, while the baking temperature requires a downward adjustment of a few degrees. Many bakers have found it advantageous to use steam only at the outset of the first bake, depending upon moisture evaporation from the baking loaves to provide a suitable degree of humidity for subsequent bakings. This practice avoids the danger of tough crusts that tend to develop with excessive amounts of steam in the oven. Pullman bread usually requires a slightly longer baking time than does round top pan bread. Rye breads and hard rolls call for both higher temperatures, in the neighborhood of 450° F., and relatively high amounts of steam, these conditions being conducive to the development of a smooth, glossy crust desired in these types of products. High sugar doughs, such as are encountered in sweet goods, must be baked at somewhat lower temperatures to prevent early and excessive caramelization of the sugars and an undesirable darkening of the crust. The same applies to white bread containing 4 to 6 percent dry milk solids. In general, relatively lean formulas require higher baking temperatures and shorter baking times, while richer formulas require lower temperatures and longer baking times. This generalization derives from the fact that sugars and milk are rather sensitive to high temperatures, undergoing rapid and pronounced browning. If dough containing high percentages of these enriching ingredients were baked at high temperatures, the crust would color excessively before the loaf had thoroughly baked through. By the same token young doughs containing a high residual sugar content require lower baking temperatures. Lean doughs, on the other hand, contain a minimum of sugars and milk so that they are lacking in those ingredients that are primarily responsible for early color formation. Hence, crust color must here depend to a greater extent upon the formation of colored pyrodextrins from starch under the influence of high intensity heat. If lean doughs were baked at normal temperatures they would bake out excessively before developing a satisfactory crust color. The same holds true of old doughs in which the sugar supply has been exhausted by too long a fer-

mentation. Because of the marked variability that exists in ovens of different designs and of even the same type in different plants with respect to heat distribution, steam conditions, etc., it is impossible to lay down exact conditions of baking for best results. These can only be determined by a practical study of actual oven conditions as encountered in individual plants and relating them to such factors as formulas used, method of proofing employed, types of products made, etc.

The most frequent faults in oven technique and baking procedure met with in practice may be listed as follows:

1. Insufficient oven heat.
2. Excessive oven heat.
3. Excessive flash heat.
4. Too much steam.
5. Not enough steam.
6. High pressure steam.
7. Improper heat distribution.
8. Incorrect pan spacing.

These conditions all lead to unsatisfactory baking results and must hence be guarded against.

Insufficient Oven Heat: Bread baked in an insufficiently hot oven is characterized by an excessive volume, coarse grain and harsh texture, a thick, pale crust, and a high bake-out loss. The large volume results from excessive oven spring made possible by the low temperature which acts too late to arrest enzymatic action and to set the crumb. The abnormal expansion of the loaf is obtained at the cost of fine grain and smooth texture. Crust thickness is greater than normal because of the prolonged drying that is inherent in low temperature baking. Also, the heat intensity is insufficient to produce adequate caramelization so that the crust color will lack an appealing bloom. Perhaps the most serious shortcoming of low oven heat is the excessive bake-out loss that results from prolonged evaporation of moisture and volatile substances. If under these conditions short-weight loaves are to be avoided, the dough pieces must be scaled heavier which, of course, entails increased production costs. The average baking loss with correct baking procedures is taken to be about 10 percent or less. Consistently cool ovens require a reduction in final proof time in the interest of better volume and texture. Cool ovens will prove satisfactory with doughs made from green or weak flours or with young doughs.

Excessive Oven Heat: Ovens which are too hot yield bread with reduced volume, dark crusts and under-baked sides. The reduction in volume is caused by the too early formation of a crust, thereby arresting.

oven spring prematurely. This may also result in an uneven grain with large flat holes caused by confining the expanding forces within too small a volume. The crust, especially with rich doughs, will take on a deep color before the interior of the loaf has been thoroughly baked and also before the side crusts have been properly developed. If the bread is withdrawn from the oven merely on the basis of an attractive crust color, the crumb will be gummy and flavorless. If the bread is permitted to bake thoroughly, its crust will be unacceptably dark. Excessive heat has also been shown to produce blisters, especially with doughs that are cold, wet, young, or made with weak flour. A hot oven is less objectionable with old and lean doughs in which case it promotes desirable crust coloration and an improved flavor. Hearth breads and hard rolls also are more successfully baked in a hot oven.

Excessive Flash Heat: Flash heat may be defined as a condition of intense heat which, however, is not supported by a corresponding amount of heat as expressed in terms of thermal units. It is normally encountered during the initial stages of baking, causing the crust to color quickly, while crumb baking proceeds at a slower than normal rate because of the rapid dissipation of the heat. The result is either a too darkly colored product or an underbaked product. Flash heat is characterized by a marked drop in the temperature of the oven shortly after loading. It should not be confused with a hot oven in which a solid heat prevails, even though some of the effects produced by both conditions are similar.

Flash heat occurs most frequently with brick ovens in which the chamber atmosphere and all or part of the chamber surface develop excessive heat during periods of idleness. When the oven is loaded, the flash heat spends itself rapidly by causing almost immediate coloring of the crust. Since neither the chamber atmosphere nor the immediate surface layers are capable of storing great amounts of heat, there is a marked drop in the temperature so that difficulties ensue in obtaining a thorough bake of the crumb. Frequently the condition of flash heat is localized in the upper air strata of the chamber and is then characterized as excessive top heat of temporary duration.

Flash heat is also occasionally encountered with modern mechanical ovens following a period of idleness. The condition is less pronounced, however, since the flexible heating system which automatically adjusts itself to baking loads tends to minimize the accumulation of excess heat during the time when the oven is idle. Also, the movement of the baking trays through the chamber tends to distribute the heat evenly so that localized over-heating is largely prevented. The occurrence of top heat or so-called "hot spots" is an engineering problem which can be overcome by proper oven design.

Several methods for minimizing or eliminating flash heat have been successfully applied by bakers. One is, of course, to so arrange the shop schedule that the oven is never completely empty during a day's run. Intervals of slow production or interruptions are best cared for by "bridging over," i.e., by running the oven partly full instead of having it remain completely empty for certain periods. Bridging over should be carried out by evenly spacing the pans farther apart or, in tray ovens, by loading every other tray, taking care with soapstone trays not to use the same ones in successive loadings. Another method is to cool the oven by opening the appropriate dampers to permit the escape of hot gases and the admission of cool air. Bakers have also adopted the use of so-called "flash pans" at the beginning of a run. These consist of old pans or other containers filled two-thirds with water, wet sand, or some other wet incombustible material. These should be used in sufficient number to simulate the normal load condition, with respect to both weight and pan spacing, of the first row of pans or the first tray.

Too Much Steam: One of the principal causes of tough crusts in white pan bread is the excessive use of steam in the oven. A proofed dough piece will register a surface temperature of about 95° F. When it is introduced into a steam-saturated atmosphere maintained at over 400° F., the steam will condense on the cool surface. This condition, while it is conducive to good oven spring and large volume, results in the formation of a tough crust and top blisters. A large amount of steam and high temperatures are ideal for the production of rye breads and hard rolls in which they give rise to a smooth, glossy, crisp crust. Too much steam in a cool oven will result in tough crusts in these products also, while not enough steam in a hot oven produces unsightly ruptures in the crust of these products.

Not Enough Steam: A dry oven shows a pronounced tendency toward the formation of shell tops in round top loaves. Somewhat of the same effect is obtained with too dry a proof which has resulted in a crust on the dough piece. In both cases, the shell top is the outgrowth of a separation of the crust from the crumb caused by a premature hardening of the top crust in loaves that would normally exhibit a vigorous oven spring. This same fault is also frequently encountered with young doughs and doughs made with strong flour. It can be minimized or entirely eliminated by employing higher proofing humidities or by injecting steam into the oven during the first five to ten minutes of baking.

High Pressure Steam: The use of the correct type of steam in the oven and, preceding that, in the proof box, plays a highly significant role in the production of quality bread. Normally, the steam used for both these purposes is so-called saturated or wet steam having a gauge pressure

of 5 to 10 lbs. per square inch. The temperature of such steam ranges between 227° to 239° F. Steam temperature increases with rising pressure, the temperature of saturated steam at atmospheric pressure being 212° F. Saturated steam is the type obtained by direct evaporation of water in a closed boiler. The water vapor itself will be present in an invisible form, consisting of individual water molecules. Wet steam, on the other hand, results from a slight cooling of saturated steam which forces the individual water molecules to condense into minute droplets and form a mist or fog. This effect may be observed wherever steam escapes into the atmosphere from a pipe. The steam is invisible immediately on leaving the escape valve, turning into a white mist only after traveling a distance of several inches during which time it has been cooled by the atmosphere. When such saturated or wet steam enters the baking chamber and comes into contact with the cool surface of freshly loaded dough, its moisture will condense upon the dough surface to produce the desired effect, frequently referred to as the steam effect. High pressure steam is also high temperature steam. Thus, at 20 lbs. gauge pressure steam has a temperature of 259° F. and at 50 lbs. pressure 298° F. When high pressure steam is introduced into the oven, the high temperature of its moisture prevents its condensation on the dough surface since the temperature must be reduced over a much wider range, requiring a longer time and giving the oven heat a chance to increase the temperature of both the steam and the dough surfaces. Hence, the normal steam effect will be absent with high pressure steam. Furthermore, this kind of steam will tend to depress loaf volume, especially with rye breads. Where only a high pressure boiler is available, the steam line leading to the oven should be equipped with a check valve or a steam expansion tank which acts to reduce the pressure of the steam, thereby bringing about a corresponding decrease in its temperature and an increase in its effective moisture saturation.

Steam lines from the boiler to the oven should be fully insulated both in the interest of economy and greater uniformity of the steam. Unprotected steam pipes radiate considerable heat which is extracted from the steam and causes it to condense into free water. Unless such condensed water is removed by means of a trap just prior to entering the oven, the steam will carry this condensate with it in the form of a coarse spray which causes surface blisters on loaves and imparts an unsightly mottled effect to the bread crust. To obtain an accurate reading of the steam pressure as the steam enters the oven, the pressure gauge should be mounted on the steam line at the point of entry into the oven. This prevents marked fluctuations in steam pressure due to varying heat losses from the lines with changing environmental temperatures, especially in

cases where long steam lines must be employed to connect from the boiler to the oven.

Improper Heat Distribution: The most widely encountered problem in this connection is insufficient bottom heat, e.g., in the hearth or oven plate. The effect of such maldistribution of heat will be bread which possesses a well-baked top crust but under-baked bottom and side crusts. While such bread is generally well baked throughout its crumb, it will nevertheless tend to collapse and cave in at the sides because it lacks the support of strong side crusts. Inadequate bottom heat is especially troublesome in the case of rye bread baking, since here the loaves tend to flatten out and break at the sides or the seam. A good solid bottom heat is one of the first essentials of quality baking.

Incorrect Pan Spacing: Proper spacing of pans is essential for even and thorough baking. Too closely spaced pans restrict the full circulation of hot gasses within the baking chamber and thereby result in irregular baking. In general, pans for 1-lb. loaves should be spaced a minimum of ¾ inch at the top rim and preferably more, while pans for 1½-lb. or larger loaves should be spaced no closer than 1 inch apart. Thus, 3-lb. Pullman pans should have a space of at least 1½ inches between them.

BREAD COOLING

The introduction of the slicing and wrapping of bread brought in its wake the necessity of accelerating bread cooling in order to maintain production schedules. Bread, unless it is properly cooled, presents certain slicing difficulties which result in frequent stoppages and crippled loaves. In addition, when bread is wrapped at relatively high temperatures, there is a tendency for moisture condensation to occur within the wrapper thereby creating environmental conditions which are highly conducive to mold growth. While no close agreement exists among practical bakers as to what constitutes optimum bread cooling, the general concensus appears to be that an interior loaf temperature of approximately 90° F. should be aimed at and that cooling conditions should be so maintained as to preclude excessive moisture loss on the one hand and insufficient moisture evaporation on the other. Just what range of moisture loss constitutes the ideal is difficult to say since this depends to a large extent upon the general baking conditions employed. Given the legal requirement that the cooled bread must not exceed 38 percent in moisture content it is evident that oven conditions which entail heavy evaporative losses call for bread cooling conditions that minimize evaporation, while oven conditions or baking times which lead to a lesser removal of moisture should be followed by bread cooling conditions that

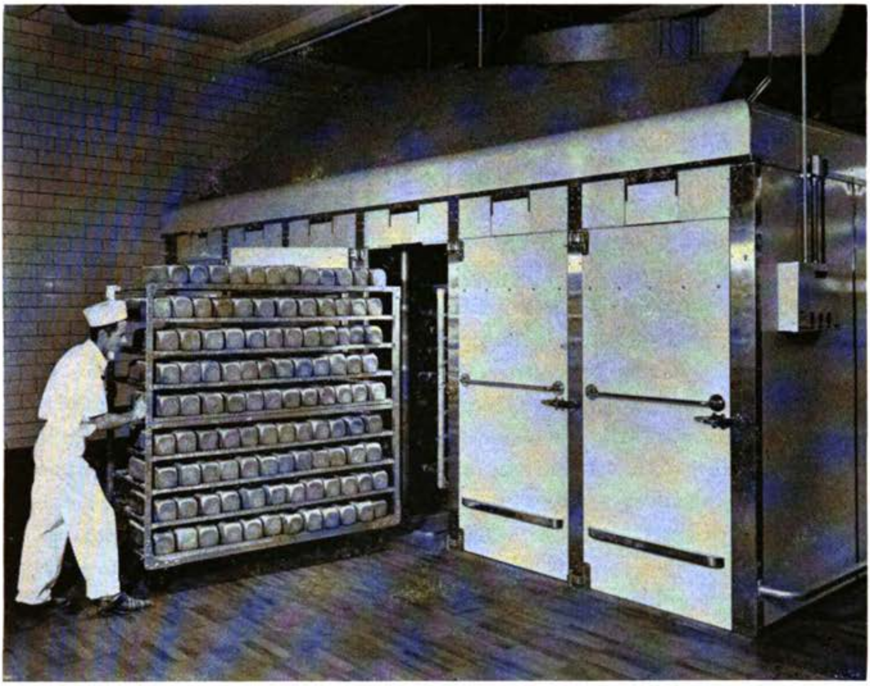


FIG. 84—Racked bread being wheeled into bread cooler. (*Courtesy Burny Bros. Bakeries.*)

promote evaporative losses. Bakeries which lack special bread cooling equipment and are therefore dependent entirely upon atmospheric cooling are nevertheless in a position to control the ultimate moisture content of the cooled loaf by making suitable adjustments in their baking conditions to coincide with seasonal atmospheric changes.

Before discussing the various types of bread cooling equipment available to the baker, a brief discussion of the physical reactions which occur within the cooling loaf might properly be injected at this point. When a loaf leaves the oven it possesses a fairly uniform temperature throughout its volume with the exception of the exterior zone constituting the crust. The temperature reduction in this outer crust layer, however, proceeds fairly rapidly through radiation so that for all practical purposes the freshly baked loaf emerging from the oven may be assumed to be of uniform temperature throughout. No such uniformity, on the other hand, exists with respect to its moisture distribution. This follows quite naturally from the fact that the outer zone of the loaf has been subjected to high baking temperatures for a much longer period than has the interior portion which attains baking temperatures only during the last few

minutes of the baking period. On removal of the loaf from the oven there occurs thus a redistribution of the moisture within the loaf, the moisture moving from the high-moisture area at the center to the low-moisture area of the crust zone. This moisture distribution accounts for the change in character of the crust which is transformed within a few minutes out of the oven from a dry, crisp condition to a perceptibly soft condition. Some form of moisture equilibrium within the loaf is thereby attained. The rate at which moisture moves to the crust zone, and from thence into the atmosphere through evaporation, will depend upon differences in vapor pressure existing within these various zones. Vapor pressure, in turn, is a function of temperature, i.e., the higher the temperature, the greater the vapor pressure and the more rapid the evaporation rate. These simple facts explain the importance of reducing the interior temperature of the loaf prior to wrapping to about 90° F. so as to bring about a corresponding reduction in vapor pressure and prevent subsequent outward movement of moisture which, within the confinement of the package, would lead to soggy crusts, moisture condensation and deterioration of loaf form.

It has been pointed out that the rate of moisture movement from the loaf interior to the crust zone and from thence into the surrounding atmosphere depends upon differences in vapor pressure. While the loaf is at high temperature, moisture will move rapidly from the interior to the exterior of the loaf. However, as the crust zone begins to cool as a result of heat loss through radiation, convection and evaporation, and as the difference in vapor pressure between the crust zone and the surrounding atmosphere diminishes, the rate of evaporation becomes more and more dependent upon the difference in vapor pressure of the crust zone and of the atmosphere. In other words, at low atmospheric vapor pressures, such as prevail during the winter months, the rate of evaporation from the crust will be rapid, whereas at high atmospheric vapor pressures, such as are encountered during summer months, the rate of evaporation from the crust will be slow. Thus in a dry atmosphere the moisture loss from a loaf may be excessive during the period required to reduce the interior temperature to the desirable level, resulting in a dry checked crust, a hard loaf, and poor keeping quality. Under humid conditions, on the other hand, the high vapor pressure of the atmosphere will prevent adequate evaporation from the crust even upon prolonged cooling so that a soggy and excessively soft loaf reaches the slicer and wrapper.

These considerations clearly establish the desirability of controlled bread cooling. Aside from simple atmospheric cooling where the loaves of bread are exposed on racks or conveyors to the atmosphere of the bakery for a period ranging from 3 to 4 hours or more, there are three

methods in which an attempt is made to accelerate the rate of cooling. Of these only two may be said to embody efforts to provide a control of the cooling conditions. The first method, and the simplest from the control standpoint, comprises a conveyor of the multi-tier type housed either in a box or enclosed in an over-head tunnel-type cabinet which is equipped with an air exhaust system. Bread from the oven is conveyed to the top run of the unit and then descends slowly in a series of stages until it reaches the discharge end ready for slicing and wrapping. The top of the cooler is provided with an exhaust fan which removes the heat radiated by the bread. Fresh air is drawn in at the lower part of the cooler, moving slowly upward and past the cooling loaves, thereby producing a cooling effect by means of both convection and accelerated evaporation. The average cooling time is reduced to 2 to 2.5 hours by this procedure, but it should be noted that it does not provide for controlling the moisture loss of the cooling loaf.

A second system of bread cooling involves the application of air-conditioning. Here bread is cooled in an atmosphere maintained at constant conditions of dry-bulb and wet-bulb temperatures which are so controlled that the loaf attains its proper conditioning within a time period of 90 minutes. Since it is possible under normal conditions to control both the temperature and the moisture content of the cooling air at the desired levels, the rate of moisture loss from the loaf is predetermined at the outset of the cooling cycle. This will hold true as long as the wet-bulb temperature of the outside air does not rise too high. Should extreme conditions of humidity occur, then the efficiency of the air-conditioned bread cooler is impaired unless refrigeration is available to remove the excess moisture from the incoming air. The amount of refrigeration required to be effective, however, is usually so great that its use is precluded for economic reasons. Thus although air-conditioned bread cooling represents a marked improvement over atmospheric cooling, it still falls short of the ideal in that it is unable to cope with extreme seasonal conditions. Air conditioned bread coolers are available in a variety of designs, ranging from box types through which the bread passes on racks, to floor and overhead tunnels in which the bread rests on slowly moving conveyors or traveling trays. The selection of any particular design or model is governed principally by structural considerations. Thus the box type coolers are more easily and economically installed than are the overhead bread coolers which generally require additional structural reinforcement of the building to support a weight of approximately 800 pounds per lineal foot of such coolers.

The most highly developed system of bread cooling is represented by the improved vacuum cooling method. Here the cooling time is reduced

to about 32 minutes. Vacuum bread coolers comprise two main sections: (1) a tempering or conditioning tunnel in which a major portion of the heat is dissipated by the loaf while being conveyed for a period of some 28 minutes through an atmosphere of warm moist air, and (2) a vacuum section which completes the cooling of the loaf. By maintaining a wet-bulb temperature setting at 80° F. in the conditioning tunnel and by adjusting the dry-bulb temperature either upward or downward, either more or less evaporation from the cooling loaves is obtained during their movement through the conditioning section. The loaves enter the vacuum

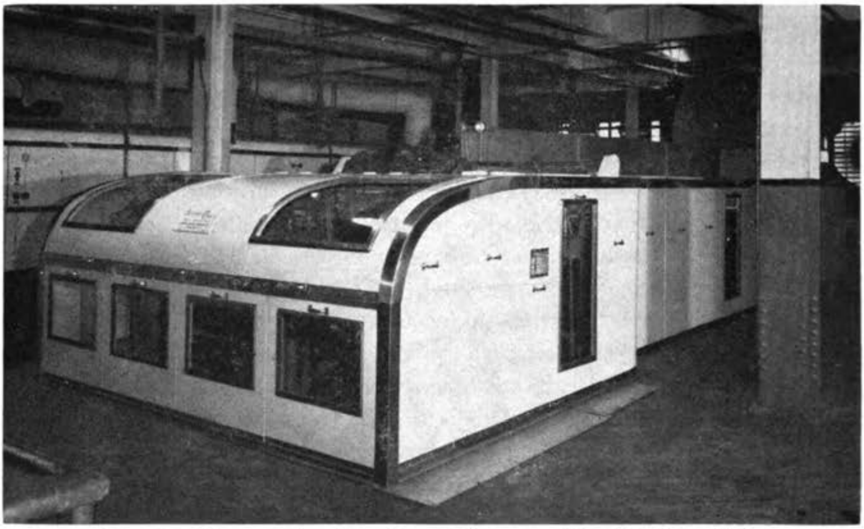


FIG. 85—Vacuum bread cooler. (*Courtesy Ward Baking Co.*)

chamber with an interior temperature of about 135° F. while their surface temperature is substantially that of the conditioning atmosphere. During their brief passage through the vacuum compartment, the reduced atmospheric pressure in that section induces a rapid release of the higher vapor pressure prevailing within the center of the loaves, resulting in an equalization of both the temperature and the moisture throughout the loaves. By proper control settings of both the conditioning and vacuum sections it is thus possible to obtain cooled bread within a minimum of time which possesses a uniformly constant moisture content regardless of the seasonal variations in atmospheric conditions. This method of bread cooling has recently been described in detail by M. H. Duval (*39*).

PARTIALLY BAKED PRODUCTS

Late in 1949, General Mills, Inc. introduced an entirely new baking concept with the so-called "Brown N' Serve" process which results in the

production of semi-finished rolls, breads and pastries that are fully formed and prebaked to exact shape and size, except for color or crust browning. The purpose of this process is to make available to the housewife bakery products of great keeping quality which she can finish baking in her own kitchen oven, thereby providing her with oven-hot bakery goods.

The "Brown N' Serve" process requires a modified formula, fermentation process, and baking condition (*40*). The objective is to bake yeast-raised products to a point of rigidity and full volume without any sem-

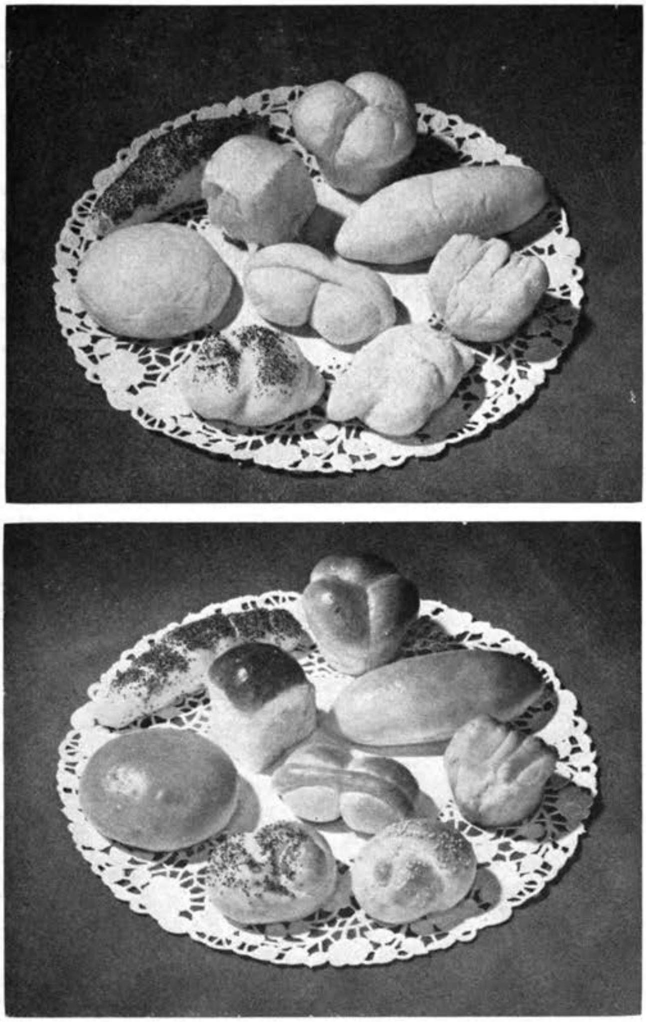


FIG. 86—"Brown N' Serve" yeast-raised products, as sold by bakers (upper photo) and as finished in the kitchen oven (lower photo). (*Courtesy General Mills, Inc.*)

blance of crust color. This is attained by reducing the oven temperature to a range of 275°-300° F., and by properly conditioning the dough so as to minimize undesirable oven spring normally resulting from baking at lower temperatures. Hence those factors that promote dough development and oven spring will have to be minimized in some formulas. In general, the following modifications of normal procedure are required for the new method: Dough consistency should be stiffer than normal to promote the desired rigidity out of the oven. Straight doughs call for higher mixing temperatures, in the range of 90° to 95° F., while sponge doughs may be mixed at normal temperature. Both the yeast and the yeast food should be reduced slightly to prevent excessive oven spring. Generally, a fairly rich formula, especially with respect to shortening and eggs, is preferable as contributing to the flavor, aroma, and eating quality of the finished product. Fermentation should proceed in a warm room. Proofing at a temperature of 100° to 105° F. is desirable as promoting a fast proof and assisting the final baking. Baking must be done within a temperature range of 275°-300° F. for as long as possible without the appearance of crust color. Given a solid heat, a baking time of 10 to 15 minutes will be adequate in most cases to impart rigidity to the product. The interior temperature of the products must be over 170° F. as they leave the oven, otherwise they will tend to collapse during cooling. The inside temperature should preferably reach 180° F. The attainment of this temperature without exterior coloration is aided by high proof temperatures. Following baking, the subsequent cooling and packaging must be done under highly sanitary conditions to reduce the possibility of mold development on the one hand and to preserve the unique appearance of the products.

CHAPTER XIX

RYE BREAD PRODUCTION

Rye bread is produced by the commercial baker in a large number of distinct varieties to meet the specific demands of local consumer preferences. Thus rye breads, given such descriptive designations as American rye, Bohemian rye, Jewish rye, German rye, Russian rye, etc., vary in crumb color from practically white to a dark gray, in shape from round to elongated loaves, and in taste from a mildly sour flavor to a strong, distinctive, acid taste strongly spiced with caraway seed or other spices. Rye bread may furthermore contain only the basic ingredients—namely wheat and rye flours, water, yeast and salt—or it may incorporate a number of additional ingredients, such as molasses, potato flour, sugar, shortening, various fruits, buttermilk, dry milk solids, etc., all designed to enhance either the flavor, or color, or keeping quality of the finished product. It is thus quite evident that among the basic types of bread, rye bread permits of the greatest number of modifications of its form, color and taste. It is therefore readily possible for the individual baker to so modify his rye bread formula as to produce the type of finished product that will find greatest appeal among the consumers of his locality.

The production of rye bread differs little in its essential steps from the production of white bread. Thus all the basic processes of wheat flour dough treatment are duplicated in rye bread production, the differences being merely of degree rather than of kind. In the following paragraphs, an attempt will be made to outline in some detail the practical procedures which have proved most successful under actual commercial production.

Although rye flour is considered in greater detail elsewhere in this volume (cf. page 237), it will prove useful to summarize very briefly at this point the basic types of commercially available rye flours. These may be differentiated into four groups; namely, white rye, medium rye, dark rye, and rye meal.

1. White rye flour is the patent from the rye grind, representing only the endosperm portion of the rye grain. It is the lightest available grade and has a very smooth texture. Consisting largely of rye starch, with a

relatively low protein content, it is particularly suitable for the production of mildly flavored, light colored types of rye bread.

2. Medium rye flour represents a straight rye flour whose ash content may range up to 1 percent, whose color is light gray, and whose texture is still smooth. It consists of the whole rye kernel with the bran removed and gives rise to a fairly pronounced rye flavor on fermentation. Its principal use is in the production of medium rye and dark rye breads, such as Bohemian, Polish, and Russian.

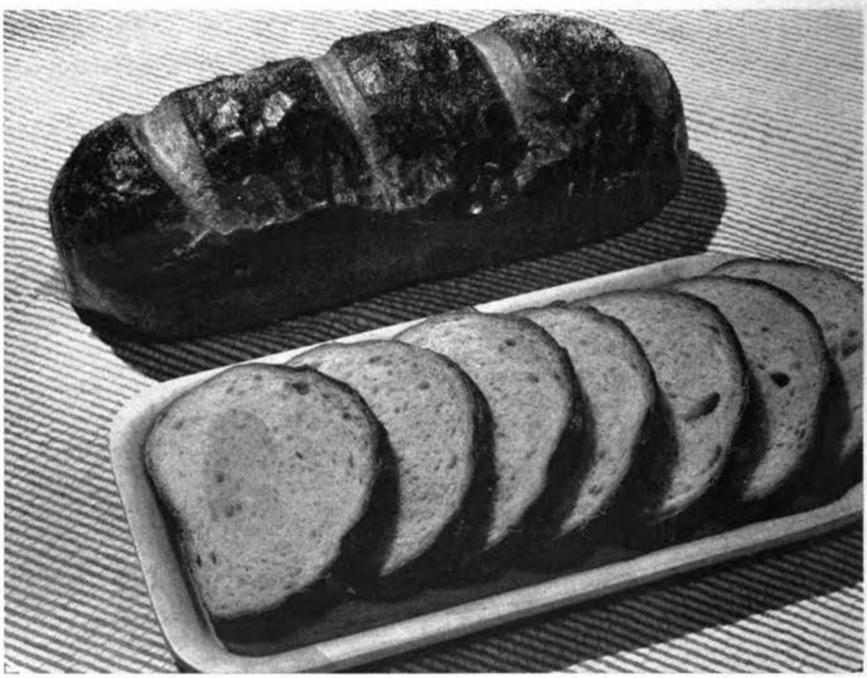


FIG. 87—American type rye bread. (*Courtesy General Mills, Inc.*)

3. Dark rye flour is a low grade product from which part of the patent flour has been removed. It may range in ash content up to 2 percent and in protein content up to 16 percent. It is dark in color, possesses a pronounced flavor, and lacks the smooth texture of the other grades due to the presence of a considerable amount of bran. It is suitable for the production of dark heavy rye bread varieties, such as the heavy German and Swedish rye breads.

4. Rye meal is whole rye flour. Its relatively coarse texture and very dark color limits its use chiefly to the production of pumpernickel.

Rye flour types may be readily differentiated by their color, the lighter

FIG. 88—Russian type rye bread. (*Courtesy General Mills, Inc.*)

flours constituting the milder, more neutral products, while the darker varieties possess the stronger rye characteristics.

The fundamental distinction between wheat flour and rye flour rests upon the fact that the proteins of the latter are incapable of producing the type of gluten on mixing with water that results when wheat flour is so treated. This absence of gluten-forming proteins in rye flour accounts for the limitation imposed upon the amount of rye flour that can suitably be incorporated in rye doughs without causing an excessive loss in bread volume. It is impossible to produce an aerated loaf of bread entirely from rye flour since a rye dough will possess neither elasticity nor gas retention ability, lacking the gluten structure upon which both these properties are based. Rye flour, therefore, represents a load upon the wheat flour used to obtain an aerated loaf. Hence, rye flour, when used in a dough beyond a certain limit, will exert a volume-depressing effect on the finished loaf. The quantitative limit for rye flour depends on two principal factors, namely the quality of the wheat flour, and the type of rye flour. As far as the wheat flour is concerned, the type most frequently used is a strong first clear flour, with strong patent and second clear flours also finding some application. The stronger the

FIG. 89—Swedish dark pan rye (Limpa). (*Courtesy General Mills, Inc.*)

wheat flour, the greater the increment of rye flour it will tolerate without losing volume. With respect to the type of rye flour, white rye flour can be used in quantities up to 50 percent of the total flour without causing an appreciable decline in loaf volume. Medium rye flour has a lower quantitative limit, approximately 35 percent, while dark rye flour exerts the most pronounced volume-depressing effect and can hence seldom be used in quantities exceeding 20 percent, if satisfactory volume of the finished loaf is one of the desired characteristics. One of the reasons for the strong effect produced by dark rye flour is that it generally contains a considerable proportion of bran particles which tend to cut and puncture the gluten film of the dough and thereby reduce the gluten's gas-retaining capacity. Hence, fineness of granulation, especially in dark rye flours, becomes an important quality consideration.

In addition to wheat and rye flours, the other basic dough ingredients include yeast, salt, and water. As has already been indicated, rye flour, because of its more favorable pH and somewhat higher contents of sugars and dextrines, possesses considerable fermentation capacity. As a result, good practice requires an adjustment of the amount of yeast in an inverse proportion to the amount of rye flour used in the formula. Thus if a

formula containing 20 percent rye flour properly calls for 1.75 or 2 percent yeast, this yeast increment is advantageously reduced to 1.5 percent when the rye flour is increased to 30 or 35 percent. Such an adjustment, with a corresponding compensation in fermentation time, results in a loaf possessing greater moisture and improved keeping qualities.

Salt must generally be used in larger amounts in rye doughs than in wheat flour doughs, the most generally recommended percentages being 2.5 to 3.5 percent based on total flour. This increased salt addition is required partly for its fermentation stabilizing effect and partly for its flavor-accentuating function.

There are, in addition to the above basic ingredients, a number of supplementary dough additives which find widespread use in commercial rye bread production. Among these, the more important ones are as listed below:

Yeast Foods—used as fermentation stimulants and dough stabilizers. Generally lower percentages are required in rye doughs than in wheat flour doughs.

Malt—used as fermentation stimulant and as an aid to crust color and flavor development. Its use must be carefully controlled to avoid difficulties with sticky doughs which might result from excessive diastatic action.

Shortening—used to obtain tender crust, softer crumb and improved keeping quality. Use of shortening will be found particularly beneficial where production is chiefly by machine.

Sugar—used to improve crust color, flavor, and to stimulate fermentation.

Molasses—used to enhance the flavor of the bread and to darken its crumb and crust color. While its use as a flavoring substance is generally approved, its role as a colorant is less widely accepted because of its tendency to impart a yellowish cast to the crumb.

Dry Milk Solids—used for improved crust color, softer crumb texture, enhanced flavor and aroma, and extended keeping quality.

Sour Milk and Buttermilk—used to accentuate taste and flavor, to stimulate fermentation by increasing dough acidity, and improve moisture retention.

Flours Other Than Wheat and Rye—these include potato flour and corn flour which are used principally as absorption boosters.

Flavoring Substances—these cover the various spices, such as caraway seed, and rye flavors and cultures whose primary purpose is to impart the distinctive flavors that characterize different rye bread varieties.

Sours. The use of so-called sours, which consist essentially of rye flour doughs fermented by lactic acid and acetic acid bacteria rather than yeast, originated long before the development of compressed yeast and has to a large measure been retained because of its desirable effect on flavor. However, whereas formerly it was the common practice of bakers to rely entirely on spontaneous bacterial fermentation to start sours, most present methods make use of yeast as the initial fermenting

agent. Sours are differentiated into several general types, their distinguishing features being their mode of preparation and their predominating acid organism. The so-called fresh sour is prepared fresh daily by mixing medium or dark rye flour with sour milk into a batter of medium consistency with the addition of approximately 0.5 percent yeast, and leting it ferment at 76° F. for a period of 8 to 12 hours. This sour is then used either in the sponge or dough in amounts of about 6 percent based on total flour.

Another type of sour is the perpetuated sour, which is maintained from day to day, the portion used up for a day's production of rye bread being made up so that the original amount of sour is again restored for use on the following day. The following formula and method is representative of this type of sour (*41*):

Milk Sours

(Basic Formula)

22 lbs. Strong first clear flour
22 lbs. Medium rye flour
33 lbs. Bulgarian buttermilk (acidity of 2%)
23 lbs. Water
1 lb. 5 ozs. Milk powder
1 lb. 3 ozs. Salt

Dissolve the salt and milk powder in the water and mix with the buttermilk. Then mix in the flour by hand. This sour should be kept in a wooden half barrel or wooden trough. Always start off with twice the amount of sour necessary so there will be enough left to start the sour for the following day. Set the above sour fresh every Saturday at least 24 hours before it is to be used. Set the first sour of the week at 85° F. Set the balance of the sours during the week at 70° to 72° F.

If 50 lbs. of the above sour is removed for use, renew as follows: dissolve 1 lb. 5 ozs. of milk powder and 12 ozs. of salt in 22 lbs. of ice water and mix in with the remaining sour. Then mix in 14 lbs. of strong first clear flour and 14 lbs. of medium rye flour. This sour will then be ready for use in 24 hours without refreshing.

Use from 9 to 15 lbs. of this sour to each 100 lbs. of flour, depending upon the degree of sourness desired. If making sponge doughs use the sour in the sponge. We also suggest with this sour the use of 1.5 percent milk powder based on the total flour and using the milk powder in the sponge.

(Variations)

The "basic formula" and methods can be used with the following types of soured milks: Acidolphilus milk, culture buttermilk, plain buttermilk. Milks containing the highest possible acidity are best.

Unpasteurized milk soured at varied temperatures will produce different flavors and these can also be used with the basic formula. Sour unpasteurized milk at 50° F. for four days, or at 65° F. for two days, or at 80° F. for one day, or at 95° F. for one day, or at 115° F. for one day. Soured at these temperatures, different types of bacteria and flavor develop.

A third procedure is to prepare a series of sours, progressing from a starter through a half-sour and whole-sour, to the final sponge and

dough, with each step requiring the mixing in of additional rye flour and water, followed by fermentation at fairly low temperatures for varying periods.

In recent years a very simple procedure for the preparation of a sour has gained rapid acceptance in Germany where it originated. Called the "Berlin short sour method," it is essentially a single-step procedure in which the starter, representing 10 percent of the total sour aimed at, is mixed in with the rye flour, which constitutes 45 percent of the total flour, at an absorption of 90 percent. After standing for 3 hours at 95° F., a portion of the sour is removed to serve as the starter for the next day's production, while the remaining sour is mixed into the dough in the usual manner, using about 1 percent yeast in the process. Since the starter does not contain yeast, it can readily be held until the following day without the need of freshening it up in the interval. The starter is preferably held at a temperature of 75° to 80° F. in order to avoid excessive acetic acid formation which occurs at lower temperatures. It is important that it be removed from the full sour only after the latter has completely ripened, i.e., after 3 hours. The starter may be held for longer periods by mixing in sufficient flour to reduce its absorption to 50 percent, this reduction in moisture exerting a stabilizing action (*42*).

A final, and at the same time most simple method is to hold back part of the sour dough from one day's production until the next for addition to the fresh sponge or dough. A sufficient amount of the bacterial flora is thereby introduced into the new sponge to produce the desired effect in the course of normal fermentation.

The flavor of rye bread is to a very large degree influenced by the relative presence of lactic acid and acetic acid. Lactic acid, being almost tasteless and odorless, gives rise to a mild flavor, while acetic acid, being highly volatile and possessing a more marked acid character, produces a strong sour flavor in bread. By a judicious selection of temperature and absorption conditions of the sour, the baker is able to control to a considerable degree the flavor character of his rye bread. The most favorable temperature range for the formation of lactic acid lies within 95°-105° F., whereas acetic acid is most rapidly formed within the relatively low temperature range of 68°-82° F. Furthermore, the higher the absorption employed, the more is lactic acid formation favored, while stiff sours promote acetic acid formation (*43*).

The use of natural sours requires considerable care and control since a change in any of a number of factors may cause the sours to alter markedly in character. Variations in type of flour, in temperature, in absorption, etc., may all act to create conditions within the sour that could bring about a complete change in the nature of the bacterial flora

as it originally existed in the dough. Hence, unless good control facilities are available to the baker, it is difficult for him to obtain consistently uniform results with sours that he maintains for more than a week or so. It is for this reason that commercially available prepared rye sours and cultures have found considerable acceptance. When manufactured by reliable firms, these products are consistently uniform in character and contribute materially to the flavor in rye bread.

While both the sponge dough procedure and the straight dough method may be used in rye bread production, the sponge method is preferred by the majority of bakers since, according to Grawert (*44*), this method has shown in practice to yield (a) better grain and texture, (b) better keeping qualities, (c) greater uniformity, (d) greater fermentation tolerance, (e) slightly larger loaf volume, and (f) better machineability of the dough. The straight dough method will, of course, produce good results also, but is generally conceded to require more careful supervision.

Whether or not to incorporate rye flour in sponges, and in what proportions, are questions which are answered differently by different bakers. As a general rule, if a characteristic rye flavor is desired, best results are obtained when sponges are made of all rye flour. In that case, absorption should be such as to yield a relatively soft sponge, applying a minimum of mixing. The absorption of different types of rye flours differs considerably, the darker types showing the higher absorptions. A fairly safe rule to follow, when all rye sponges are used, is to consider dark rye flour to have an absorption of 200 percent, based on flour weight, medium rye flour to have an absorption of 150 percent, and white rye flour to have an absorption of 100 percent. Depending upon the type of bread aimed at, and to some extent also upon the type of rye flour employed, either all, part or none of the rye flour may be used in the sponge. It should be kept in mind, however, that the increment of rye flour in the sponge exerts some influence upon the rate of fermentation. Dark rye flours, apparently because of their greater acidity and possibly also higher diastatic activity, tend to mature noticeably faster than do light rye or wheat flours. Depending upon both the type of flour and the amount used in the sponge, the rate of sponge fermentation will vary when either of the factors is altered.

The mixing of rye sponges and doughs must be carried out with due regard to the instability inherent in rye flour doughs. Thus, although the basic purposes of the mixing of rye doughs are essentially the same as of wheat flour doughs,—namely the thorough dispersion of all the ingredients into a homogeneous mass and the mechanical development of the wheat flour gluten to aid subsequent cell structure formation—the actual procedure by which this goal is achieved must be modified to some extent to

suit the different conditions that prevail in the rye dough. The general recommendation is to mix rye sponges and doughs at slow speeds since these doughs are very readily over-developed, causing them to become sticky and to yield small loaf volume. However, it is also quite possible to mix rye doughs at high speed with excellent results. Just what type of mixing treatment is to be given to a rye dough depends principally upon the kind and amount of rye flour used and upon the strength of the wheat flour. In practice, the greater the proportion of rye flour in the formula, and the darker the rye flour, the slower should be the mixing speed and the shorter the mixing time. At the dough stage young sponges generally impart greater tolerance to the dough than old sponges, so that in the former instance both the time and the speed of mixing can be advantageously increased. Frequently, mixing speeds are varied from slow to high at different stages of the mixing process. For example, Tesch (*45*) advances the following recommendations: Rye doughs containing 35 percent or more of medium rye flour are preferably mixed at slow speed. Doughs containing less than 35 percent rye flour (20 to 35 percent) may be mixed at high speed. However, they yield best results when mixed during the initial stage at slow speeds and are finished off at high speed. This procedure is claimed to result in better moisture retention in the finished loaf, with volume and texture being equal to those obtained with high speed mixing throughout. Nevertheless, general practical experience supports the contention that slow speed mixing is preferable with rye doughs, if for no other reason than that it reduces the danger of mechanical over-development of the doughs.

The importance of temperature to flavor development has already been indicated. General American practice is to keep sponge temperatures relatively low, within a range of 73° to 78° F., to favor the development of the tarter acetic acid, thereby obtaining a more pronounced sour taste. Dough temperatures are slightly higher, the recommended range being 77° to 80° F.

Properly fermented rye doughs should not cause any unusual problems during mechanical make-up, especially if the doughs contain less than 50 percent of medium rye flour. Standard dividers and rounders handle rye doughs as readily as they do wheat flour doughs. Sponge doughs, being more pliable, drier, and less gassy than straight doughs, will adapt themselves particularly well to divider and rounder operations. Thus they pass through the divider with less punishment and more accurate scaling, and through the rounder with a minimum need for dusting flour.

The individual dough pieces, having gone through the intermediate proofer, should offer no difficulties at the moulder, providing that the proper adjustments are made on the machine. Because rye doughs tend

to dry at the surface during the intermediate proof, it is desirable to have the head rolls of the moulder corrugated to provide an instant grip on the dough piece and thereby prevent doubling-up. The sheeting rolls should preferably be narrow so that they will produce long narrow sheets of dough which will facilitate compact curling. Both the curling rolls and compression boards should be so adjusted as not to compress the dough piece too tightly since this may lead to breaks in the baked loaf. Compression should be just enough to yield a well moulded dough piece.

The final proof of the moulded pieces should be carried out at a temperature of 92° to 95° F., which is slightly lower than the level recommended for white bread, and at a relative humidity of 85 percent, which coincides with that of white bread production. In general, an average proofing time of from 35 to 45 minutes should suffice for most conditions. The correct degree of proof is largely governed by the previous and subsequent handling of the dough and must be determined by practical experimentation and observation. Very general rules applying to rye dough proofing include the following: The darker the rye doughs, the less proof do they require. Also, the greater the percentage of rye flour in the dough, the shorter the proof should be. Doughs containing 2 percent yeast require a shorter proof time than when lower yeast additions are employed. Also, doughs with low salt contents, i.e., 1 to 1.5 percent, proof somewhat faster than do such containing 2 to 3 percent of salt.

The practice of cutting light rye loaf and docking heavy rye doughs is less widespread at present than it was formerly. Experience has shown that cutting is not necessary to the production of good rye bread and, unless performed mechanically at the moulder, it does involve the use of costly labor. On the other hand, the dough pieces should not be cut too early as this may cause the loaves to open too much and flatten in the oven. The purpose of cutting, which is to produce a symmetrical loaf, is best attained by cutting the doughs just before they enter the oven.

Many bakers lacking the facilities of an automatically humidified proof box resort to the practice of washing the loaves either with water, a thin gelatinized starch solution, or a little egg wash, in an effort to keep the surface of the loaf moist and thereby prevent surface cracks during baking. Even where proper proofing conditions exist, washing the surface with a starch solution or egg wash is desirable as a means of imparting certain crust characteristics, such as superior bloom or a high gloss, to the finished loaf. An important point to observe in this connection is not to wash loaves after they have been cut.

Rye bread in general requires a stable, solid heat within a temperature range of 470° to 500° F. for proper baking. Rye doughs from which milk and sugar are omitted require the higher temperature, as do doughs

made with the lighter rye flours. Darker rye doughs have a tendency to color more rapidly because of their greater diastatic activity and are hence properly baked at the lower temperature.

The correct control of oven conditions is of the utmost importance to the proper baking of rye bread. The oven heat must be so adjusted as to produce a uniform crust on both bottom and top of the loaf. This means that drastic differences between top and bottom heat must be avoided. Excessive bottom heat results in too rapid an oven spring which is accompanied by the appearance of unsightly cracks and round bottoms. On the other hand, too low a bottom heat fails to produce an adequate expansion of the loaf so that it will assume a flat form.

Not all ovens are equally adapted to rye bread baking. As a rule, an oven with a low crown will be found to be superior to one with a high crown for this purpose. The reason for this lies in the fact that both steam conditions and top heat constitute highly critical factors which are more readily controlled in a shallow baking chamber. Because of the restricted overhead room in a low crown oven, the steam injected into the oven and that evaporated from the baking loaves remains in more intimate contact with the loaves, since it cannot escape elsewhere. During the early stages of baking, while the loaves are still cool in relation to the oven atmosphere, there occurs a natural condensation of steam on the loaf surfaces which promotes loaf symmetry and oven spring without the appearance of unsightly cracks. Rye bread can, of course, be successfully baked in practically all types of ovens, provided that proper steam conditions and top and bottom heats are maintained. The use of low pressure steam is essential in this connection since it carries more moisture and also releases its moisture more readily in the form of condensation than does high pressure steam.

Most rye bread produced in wholesale plants reaches the consumer sliced and wrapped. The necessity of slicing rye bread has been responsible for the fact that the baking of rye bread directly on the hearth is slowly passing from the scene. The reason for its discontinuance is that hearth-baked loaves lack uniformity of length which causes difficulties in slicing. This problem has been solved by the use of so-called basket pans which produce loaves of uniform length and with blunt ends. However, this change in baking procedure is felt by many to entail a loss of flavor in the finished loaf.

Practical experience has underlined the greater suitability of the reciprocal slicer to rye bread slicing as against the band slicer. The principal reason for this difference in slicer performance lies in the fact that the reciprocal slicer, because of its alternating cutting action, is less subject to the gumming up of blades than is the band slicer in which the blades

travel continuously in one direction. The use of shortening, as has been pointed out previously, greatly reduces the tendency of rye breads to gum up slicer blades. Slicing is further facilitated by the proper cooling of rye breads, which should not reach the slicing machine until the interior loaf temperature has reached 90° F. or less. As a rule, rye bread requires a longer cooling period than does white bread under otherwise identical conditions. The manner in which a loaf will slice is to a large extent determined in the oven. Thus, unless fairly uniform crust formation is obtained during baking, the loaf will disform on being fed through the slicer blades.

The following formulas (*46*) are representative of the four basic types of rye bread being produced by American bakers.

American Rye Bread

First clear wheat flour Second clear wheat flour	85-60%
Patent white rye Medium rye Dark rye	15-40%
Water	55-65%
Salt	2-2.5%
Yeast	1.5-2%
Optional	
Malt extract or sugar	0-3%
Yeast food	0.25-0.5%
Shortening	0-3%
Caraway seed	0.5-1.5%
Sour	0-5%

This formula produces a fairly light rye, with good volume and a soft texture. Color may be controlled by suitable selection of white rye, medium rye and dark rye proportions. Generally, no sour is used in the production of American rye.

Sour Rye Bread

First clear wheat flour Second clear wheat flour	100%
Sour: Rye flour Water Old dough	40-60%
Water	50-60%
Salt	2-2.5%
Optional	
Malt extract (preferably not used)	0-1%
Caraway seed	0.5-1.5%
Shortening	0-2%
Yeast	0.25%
Yeast food	0.25% max.
Prepared cultures	4-6%

This formula will yield a rather heavy rye bread. Color can be controlled by the selection of the appropriate type of rye flour. All the rye flour is used in the sponge with this type of bread.

Pumpernickel

Clear flour	90-80%
Rye meal	10-20%
Sour { Rye flour, Water, Old dough }	15-40%
Water	50-60%
Salt	2-2.5%
Shortening	2%
Molasses	2-4%
Optional	
Yeast	0.25-0.5%
Malt extract	0-1%
Bread crumbs	0-25%
Yeast food	0.25-0.5%

This formula lends itself to the production of both light and dark pumpernickel, depending upon the type and proportion of rye flour used.

Sweet or Pan Rye

White rye	10-40%
Clear wheat flour, Patent wheat flour	90-60%
Water	55-65%
Salt	1.75-2%
Yeast	2%
Shortening	2-4%
Cane or dark syrup	10-20%
Optional	
Milk (powdered or condensed)	4-6%
Yeast food	0.25-0.5%
Malt extract	0-2%
Molasses (Limpa flavor)	5-10%

This formula produces a rather light, sweet, and highly flavored rye bread.

Salt-rising bread. This type of bread differs in several respects from normal white bread. It is characterized by a close-grained crumb, a smooth dark crust and a unique aroma and taste resembling somewhat that of mild cheese. In its eating quality it is quite "short" and also cake-like, disintegrating readily on chewing. These characteristics are imparted to this product by a fermentation in which yeast is replaced by certain bacterial cultures available commercially in the form of a dry product. Kohman (47), who developed the commercial ferment, states that the production of salt-rising bread is even simpler than that of normal bread. The process involves scalding a weighed amount of the ferment mixed with dry milk in boiling water. The cooled suspension is then used for setting the sponge in the usual way and allowing it to rise until it begins to drop, usually after one and a half hours. At this point

the dough is mixed in the usual way and taken directly to the divider, floor time being omitted. The name "salt rising bread" appears to have originated from the fact that originally salted batter was used as its leaven, the early view being that salt was in some way responsible for the aeration of the dough.

CHAPTER XX

THE STALING OF BREAD

All baked products possessing a spongy crumb are subject to a progressive deterioration of quality commonly referred to as staling. As a general rule, the higher the practical moisture content of the baked product in its initial fresh state, the more pronounced are the changes which occur upon staling. Thus such products as bread, yeast-raised sweet goods, and cakes stale to a much more marked extent than do such products as cookies and crackers. In fact, the shelf-life of the latter products is frequently limited by the stability of the shortening used, the actual staling reactions occurring at an almost imperceptibly slow rate.

Since loss due to bread staling is economically of the greatest significance, attention has centered principally upon this problem. Practical efforts with regard to retarding the staling of bread have been primarily in the direction of modifying the bread production process and of adding softening and moisture-retaining substances to the formula. A great deal of scientific investigation has also been done and the ultimate solution of the problem, if such is ever attained, will come through scientific research.

At the present time the core of the problem is still largely a matter of conjecture and speculation, no single theory of the staling process having been advanced upon which a majority of investigators are able to agree. In view of the complex nature of bread substance and the difficulties which adhere to the study of isolated factors, the relatively modest progress made thus far is not surprising. Yet before a decisive advance can be made in extending the fresh state of the bread, a clear understanding of just what happens when bread stales is essential.

In considering the changes which accompany the staling process, it is desirable to distinguish between crust staling and crumb staling. These two types of staling reaction are by no means similar, at least in their outward effects. The crust, which in its fresh state is dry, crisp and brittle becomes, upon staling, soft and leathery. Its appealing flavor disappears entirely, leaving a residual flavor which is unpleasant and is frequently characterized by a faintly bitter taste. The principal reaction which occurs in crust staling is the transfer of moisture from the interior of the loaf to the crust. The crust possesses considerable hygroscopic

properties so that it readily absorbs the moisture which diffuses outward, becoming soft and leathery in the process. The wrapping of bread contributes to the staling rate of the crust since it prevents completely the evaporation of moisture from the crust to the surrounding atmosphere. This explains why crust staling occurs much more rapidly with wrapped bread than with unwrapped bread. When the relative humidity of the air is high, crust staling is also accelerated since moisture evaporation is retarded. Cathcart (*48*) states that if the humidity is great enough, the crust may even take up moisture from the air. The increase in moisture of the crust is accompanied by a loss and deterioration of its flavor. Just what causes this adverse flavor reaction is not known, principally because the actual composition of the crust is as yet little understood.

Whereas crust staling is marked by a softening of texture, the staling of the crumb is characterized by a reverse reaction, namely the hardening of the texture. The crumb becomes tougher and more crumbly as bread stales. There is a marked deterioration in flavor, comprising both the aroma and the taste of the crumb. As staling progresses, there also occurs a moisture loss. While all of these changes probably occur simultaneously, their rates differ and they do not become manifest at the same time. Thus Alsberg (*49*) considers the order of these changes to be 1) a hardening and toughening of the crumb; 2) the appearance of crumbliness; and 3) the loss of moisture by evaporation, which occurs much later. In addition to these readily apparent changes, there are others which are less discernible. Thus it has been found that the amount of water-soluble starch which can be extracted from a stale crumb is less than that obtained from fresh crumb. It has also been observed that fresh crumb swells more when placed in water than does stale crumb. Nearly all of these changes serve as the basis of methods designed to measure the extent of crumb staling.

Theory of Crumb Staling. Numerous theories have been proposed in the past to explain the nature of the staling process, but it is only within recent years that a clearer concept of starch structure and the availability of more refined research methods have resulted in some tangible progress toward a clarification of the underlying reactions. It is not within the scope of this discussion to detail all of the observations and views which have been recorded. Geddes and Bice (*50*) have prepared a comprehensive review of the subject, covering the literature up to 1946. In the following paragraphs only the more important studies will be briefly indicated.

It was formerly thought, and this concept still prevails among consumers, that staling of bread crumb was due entirely to loss of moisture. However, about a century ago, Boussingault (*51*) was able to show that

bread staled even when kept under conditions which precluded all losses of moisture. He also found that such stale bread, which had retained its moisture content, could be rendered fresh again by heating it at a temperature of 60° C. or higher. This observation has been subsequently confirmed by many other workers and now finds general practical application in home and institutional cooking when especially buns and rolls are reheated to make them fresh again. However, von Bibra (*52*) has found that bread whose moisture content was less than 30 percent could no longer be freshened by reheating.

Lindet (*53*) appears to have been the first to associate the phenomenon of starch retrogradation with staling, interpreting the decrease in soluble starch upon staling of the bread crumb as being due to the loss of moisture in the starch through retrogradation, or the partial reversion of the starch from an amorphous, partly gelatinized form to a less hydrated, crystalline state with the liberation of moisture which is then absorbed by the gluten. With this concept of starch retrogradation, Lindet introduced a new and fruitful idea into staling research which was greatly expanded by Katz and more recent workers. Katz (*54*) in particular has investigated the problem with more refined tools of research and has made some important observations. Briefly, Katz found that all breads were subject to staling, provided they contained sufficient water, and that the degree of staleness was a function of temperature. Thus staling could be stopped either by drying the bread below a minimum moisture content or by soaking the bread in water and thereby providing an excess of moisture. Geddes and co-workers (*55*) confirmed the findings of Katz in studies on the effect of moisture content on staling over a period of seven days. On the basis of crumb swelling capacity, bread crumb containing 16.4 percent moisture did not stale. Also, by drying the crumb, staling could be checked at any desired degree of staleness. At moisture contents above 16.4 percent and up to a maximum of 36.8 percent, staling occurred at a rate which progressed with increasing moisture content. On the other hand, the crumb did not stale in excess water. As regards the function of temperature, Katz found that bread kept under controlled moisture conditions for 24 to 48 hours remained fresh when the storage temperature was 60° C. or above, became half stale at 40° C.; nearly stale at 30° C.; stale at 17° C.; very stale at 0° C.; still more stale at −2° C.; half stale at −8° C.; and remained fresh when stored at −10° to −185° C.

Subsequently Katz supplemented his earlier studies with X-ray diagrams. He found that fresh crumb gave a so-called V-pattern which is indicative of the amorphous form in which the starch is present. Upon staling, the X-ray spectrum tends to revert to the B-pattern which is

exhibited by starch in its original crystalline form. Since these same observations can be made on retrograding starch paste, he concluded that bread staling results from starch retrogradation.

Not all workers have been in agreement with Katz in his contention that staling is due principally to starch retrogradation. Thus Ostwald (*56*), while conceding the importance of the role of starch in staling, believed that the change in the starch is one of syneresis or extrusion of water induced by an internal aggregation and dehydration. Alsberg (*57*) pointed out that starch retrogradation is a relatively slow process, whereas staling proceeds quite rapidly. However, subsequent workers have shown that the rate of retrogradation of starch pastes increases markedly with increasing starch concentration. Fuller (*58*) advances the view that staling is principally a matter of a decrease in the hydration capacity of starch gels with time, and that retrogradation and syneresis are merely manifestations of that phenomenon.

More recent work by Schoch and French (*59*) suggests that staling is associated with the gradual and spontaneous aggregation of the amylopectin or B-fraction of starch, giving rise to a crystalline structure throughout the crumb. Unlike retrogradation, this aggregation is readily dissolved by moderate heating. This aggregation or coacervation is attributed to an inter-molecular association between the linear branches of the amylopectin fraction which is much less firm than that involved in the retrogradation of amylose or the A-fraction.

Bachrach and Briggs (*60*) found that a small but significant increase in the water-binding capacity of stale crumb occurs during staling. Since this increase in water-binding capacity amounts to only about 0.01 g. of water per gram of dry crumb, it is of no importance as a means of changing the structural properties of bread through the mechanism of removal of water in its role as a plasticizing medium. The structure developed in staling is due to the formation of cross-linkages between the nonaqueous elements of the bread substance. The small amount of water additionally bound during staling would indicate that the cross-linkages formed involve some water molecules. Since the same observation of increased water-binding capacity was made on retrograded starches and amyloses, the authors believe that these substances are responsible for the structural evidences of staling in bread crumb.

The above brief review of staling theories is by no means complete, yet from what has been said it is readily apparent that the problem is indeed complex. For a more complete key to the pertinent literature the reader is referred to the review of Geddes and Bice (*50*).

Methods of Measuring Crumb Staling Rate. It has been indicated above that the staling of bread crumb is accompanied by a number of

measurable physical changes which serve as the bases of methods designed to disclose the degree of staleness. The methods used most widely include those which measure the compressibility of the crumb, and the swelling capacity of the crumb. Other methods which have been used in the past have been based on the changes in the amount of water-soluble starch during staling (*54*), the changes in X-ray diffraction patterns (*54, 61, 62*), the increase in crumb opacity on staling (*63*), the reduced susceptibility of retrograded starch to amylase attack (*64*), and the changes which occur in the crumbliness on staling (*55*). Of all these latter methods, the last one appears to be the simplest, but requires further development.

Compressibility of crumb and absorptive capacity of crumb are two characteristics which can be measured accurately and by simple procedures. Compressibility methods have been described by Bailey (*65*), Combs (*66*), Noznick and Geddes (*67*), Platt and Powers (*68*), and Straub and Hirsch (*69*). The instruments described by the various authors all operate on the same principle which involves subjecting the bread crumb, usually in the form of a slice of specified thickness, to a specified weight for a given time period and observing the amount of compression obtained. A typical compressibility apparatus is that devised by Platt (*70*). This apparatus is essentially a large balance with a plunger attached to the underside of the right-hand pan. A disk is provided under this pan on which a uniform piece of bread crumb 1½ inches thick is placed, the height of the supporting disk being so adjusted that the plunger just touches the top surface of the bread crumb. A 200-gram weight is then placed on the right pan and a chain of equal weight on the left pan. To steady the pointer of the balance for the initial reading a 2-gram weight is placed on the right pan which is just enough to hold the plunger down lightly. After the initial reading is taken on the balance scale, the chain is slowly removed by means of an attached string which runs over an overhead pulley and is attached at its other end to a windlass equipped with a crank. One minute after the removal of the chain has been started, a second reading is taken and the difference between the two readings represents the compressibility of the crumb. This procedure is both simple and rapid and is therefore well adapted for use in the bakery laboratory for following the staling rates of different products.

Platt and Powers (*68*) have described an apparatus designed by J. C. Baker for measuring the compressibility of bread crumb which has been widely adopted. It is shown in the following Figure 90. The slice of bread, placed as shown, is acted on by plunger A, adjustment having been made for the thickness of the slice by the nut B. The slice

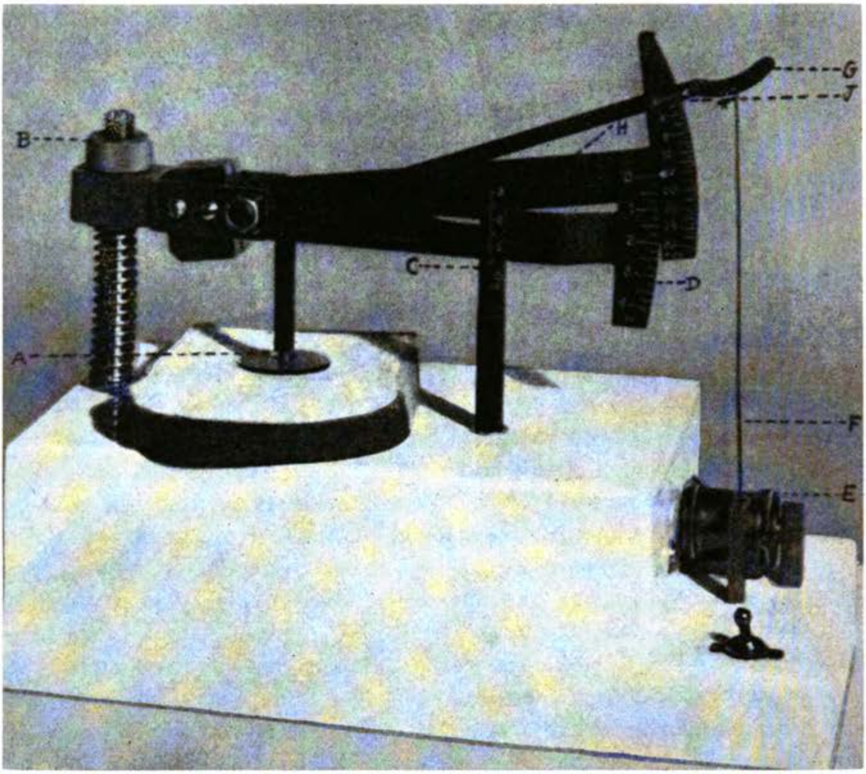


FIG. 90—Apparatus of J. C. Baker for the measuring of compressibility of bread. (*Courtesy Cereal Chemistry.*)

thickness is indicated directly in millimeters on scale C. A motor and shaft located below the bed of the apparatus slowly turns drum E, about which the string F is wound, causing the lever G to be depressed. This lever is connected to lever H through a coil spring. Scale J indicates at any moment the amount of the stress and scale D gives the corresponding amount of depression in millimeters. The drum E is so attached that it will slip on the shaft thereby permitting the drum to be adjusted, wound, unwound, or stopped with the fingers, regardless of the motion of the shaft. In making a determination, the string is loosed, the plunger raised, and the slice inserted under the plunger. By means of the nut B the pointers are then adjusted to zero on both scales. The motor is then switched on, which revolves the drum and depresses lever G at a uniform rate. After the lever has reached a predetermined point on scale J, the corresponding depression is read on scale D. The further movement of the drum is stopped with the fingers and the motor switched off. The drum is then unwound to relieve the

tension and to permit the levers to return to their normal positions. The Baker compressibility apparatus has been found reliable and convenient to operate.

In study the effect of several variables on crumb compressibility, Platt and Powers found that increasing the dry milk solids in the bread formula from 0 percent to 6 percent significantly increased the softness of the crumb. Dry milk solids of good baking quality gave a greater increase in softness than did those of poor baking quality. Increasing the amount of sugar from 2 to 6 percent did not result in a significant difference of crumb compressibility, whereas a similar increase of shortening produced a markedly softer crumb. Optimum mixing, fermentation and baking also contribute to crumb softness.

Methods which measure the swelling of crumb have been described by Katz (*71*), Cathcart and Luber (*72*), and Schoch and French (*59*). A viscometric method which also measures the absorption changes by means of a determination of the mixing strength of a crumb-dough in the farinograph was devised by Fuller (*58*).

Cathcart and Luber (*72*) modified the swelling power method of Katz by introducing the use of a centrifuge for determining the amount of sediment, and by using a 200-mesh sieve instead of a bolting cloth. The method, as given by these authors, is as follows:

"Ten grams of bread crumb, taken from near the center of the loaf, is weighed to the nearest 0.1 g. and placed on a brass-frame, 200-mesh sieve of 5 inches in diameter; the sieve in turn is placed on a 2-liter pyrex beaker which serves to catch the washings. The bread is moistened with water at 20° C. The sieve is transferred to a second beaker and the bread rubbed through with the forefinger and the second finger. The washings from the first beaker are used to moisten the crumb as the rubbing is continued. Water is added and rubbing is continued until all of the bread has passed through the sieve. The sieve is then placed back on the first beaker and the entire mash is washed back through the sieve. Care must be taken that the volume is not over 250 cc. The suspension is then transferred to a 250-cc. graduate and the solution made up to 250 cc. The graduate is shaken well and a thoroughly clean centrifuge tube (type A, 30 cc., graduated in 0.1-cc. divisions from 0 to 3 cc., in 0.2-cc. divisions from 3 cc. to 10 cc., and in 0.5-cc. divisions from 10 cc. to 30 cc.) is filled immediately. The tube is then centrifuged for 2 to 4 minutes (time must be constant) at 1400 r.p.m., when wheel of centrifuge is 10½ inches in diameter. The time and speed can be altered and standardized for wheels of different diameters."

With this modified method, a determination can be made in about 30 minutes, the readings are made more accurate since the centrifugation greatly reduces the irregularities in the surface of the sediment, and the results are highly reproducible.

It should be generally kept in mind, however, that chemical staling does not necessarily coincide with what might be called practical staling, or staling which is perceptible by organoleptic tests. As Cathcart (*48*) points out, physical tests in general show that the crumb of bread is stale long before the consumer thinks so. Thus the greatest changes in swelling power, compressibility and soluble starch occur within the first nine to ten hours after baking, or at a time when most consumers would adjudge the bread to be fresh. For example, King and co-workers (*73*) have found that the judges on a taste panel, in comparing 12, 24, and 48 hour old bread, showed a decided preference for the 12 hour old bread on the basis of flavor and taste. In applying the physical tests, therefore, the importance of supplementing their results with organoleptic or taste tests should not be overlooked.

CONTROL OF STALING

Various methods have been developed for retarding the crumb staling process, including heat, refrigeration, wrapping, ingredients and production procedures. The two most effective methods, namely heat and refrigeration, have found little commercial acceptance because of their otherwise impractical nature.

Heat. While it has long been known that reheating bread will freshen it provided it contains sufficient moisture, Katz (*7*, *24*) studied the effects of holding bread at elevated temperatures for relatively long periods. He found that bread stored for 36 to 48 hours at 60° to 90° C. retained its fresh characteristics completely, if proper humidity control was provided, whereas the same bread kept at room temperature for corresponding periods became stale. Katz and subsequent investigators believed that no staling whatsoever occurred at 60° C., but Fuller (*58*) reported that staling at a very slow rate does take place even at that temperature. The chief limitation to this method of preserving the freshness of bread is the practical difficulty involved in preventing disturbing bacterial processes from developing within the crumb. Usually, the penetrating off-aroma produced by bacterial growth becomes apparent after 12 to 24 hours, rendering the bread unsaleable. Another difficulty is that the humidity conditions of the storage cabinet must be closely controlled to prevent the crust either from becoming soft and leathery or from drying out unduly. Cathcart (*48*) expresses the opinion that "this method does not seem to offer practical possibilities due to development of the penetrating off-aroma and due to the crusty flavor which is generally imparted to the crumb."

Refrigeration. Numerous authors have reported upon freezing experiments with bread. Bailey (*74*) found that bread stored three days at

−9° C. and then thawed had the characteristics of fresh bread. Cathcart (*75, 76*) and Cathcart and Luber (*77*), in experiments with commercial type bread and employing laboratory and commercial freezers have found that bread stales rapidly at temperatures of −22° C. as judged by the swelling-power test. However, when aroma and taste tests were employed, the bread remained fresh for 30 days. At a temperature of −35° C. the bread retained its organoleptic freshness for some 70 days. There was some initial chemical staling, but a refreshening occurred subsequently so that two months after initial freezing the results of the swelling-power test closely approximated those obtained with bread only 8 hours out of the oven. Bread sealed in air-tight containers and frozen at −22° C. remained in good condition and was saleable up to 345 days (*76*). The development of an off-aroma was the limiting factor for the time the frozen bread could be kept. Onnes (*78*) reported on a commercial application of the freezing method. In this instance, the bread was cooled for three hours at room temperature and then placed in a freezing unit maintained at −25° C. Crushed dry ice at a ratio of 50 pounds per 1000 pounds of bread was placed on the bottom layer. Two hours after charging, the temperature of the freezer had dropped to −20° C., at which temperature the bread could be kept completely fresh for two weeks. The usual storage period of the bread, however, was 30 hours. The frozen bread required two hours to thaw and attain a palatable condition, after which time it had the characteristics of eight hour old bread. The excessive cost of the freezing operation, which amounted to 1¼ cent per pound, forced its abandonment. While deep-freezing of bread as a method for preventing staleness has thus far shown the greatest promise, the principal limiting factor for its widespread application on a commercial scale is the relatively high cost of refrigeration.

Wrapping. The practice of wrapping bread was originally introduced for the twofold purpose of keeping the bread in a sanitary condition and to reduce moisture loss to a minimum. Although wrapping does not retard chemical staling, it does have a favorable effect insofar as it prolongs the bread's shelf life by preserving the aroma, flavor and softness of the bread far beyond that of unwrapped bread. Longer retention of crumb softness appears to be largely a matter of decreased moisture loss in wrapped bread. Thus Martin (*79*) has found that in 6.5 days, wrapped two-pound loaves lost only 0.85 percent in weight, whereas unwrapped loaves lost 12.4 percent moisture in summer and 10.25 percent in winter. Cathcart (*48*) mentions the results of moisture loss studies on sliced, moisture-proof wrapped bread which showed that from the time of wrapping until the bread is 72 hours old, about 2 percent of moisture is lost. Moisture loss from unwrapped loaves occurs mostly in

the outer half-inch layer of crumb, giving rise to a hard, dry crumb just underneath the crust. This condition becomes evident in about 24 hours with unwrapped bread and is completely prevented by wrapping in moisture-proof material. Wrapping allows the moisture in bread to equalize itself between the crumb and the crust. The change in the distribution of moisture in the crust and the crumb of bread sealed in cans, which thus approximated wrapped bread, was followed by Geddes and co-workers (*55*) over a 12 day period of storage. They found that the crust after baking had a moisture content of 15.4 percent, and the crumb 45.1 percent. By the sixth day, the crust moisture had increased to 27.3 percent, and the crumb moisture decreased to 37.0 percent. On the twelfth day, crust moisture was 28.1 percent and crumb moisture 33.9 percent. The moisture values of the outer crumb, i.e., the half-inch layer just under the crust, which in unwrapped bread usually becomes hard in 24 hours, were 44.9, 32.3 and 31.8 percent for the respective days, and thus followed rather closely the moisture loss of the interior crumb.

Berg (*80*) investigated the effect of the temperature at which bread was wrapped upon its keeping quality and organoleptic properties. Bread samples were wrapped at 114°, 99.9°, 87.5° F. and allowed to cool slowly, and at 88.1° F. and cooled quickly in a refrigerator. Forty-four observers participated in evaluating the breads for keeping quality, i.e., freshness and freedom from mold, for odor and for taste after storage of approximately 36 hours. Warm wrapping at 114° F. was judged to give the best keeping quality, but the poorest odor and taste. Medium warm wrapping at 99.9° F. was rated third best in all respects. Cool wrapping at 87.5° F. gave poorest keeping quality, but best odor and taste. Cooling rapidly after wrapping at 88.1° F. was rated second best on all points.

Ingredients. Numerous substances have at one time or another been proposed as retarders or inhibitors of the bread staling process. As a general rule, substances such as volatile and water-soluble aldehydes and strongly basic substances such as pyridine and dipropylamine (*54*), which show a strong retarding effect, are either toxic or malodorous and therefore possess no practical significance. The search for staleness retarders has consequently centered upon naturally occurring food or edible substances, such as flour, milk products, protective colloids, gelatinized starches, dextrines and sugars, malt extract, soya flour, glycerin, shortening, etc. More recently, certain proprietary products have been offered to bakers as so-called bread softeners or anti-staling agents. While these products do in some cases tend to impart a greater softness to fresh bread, none of them has thus far been shown to materially retard staling as determined by such tests as compressibility, crumbling and farinograph measurements. In this connection it might be well to recall the follow-

ing statement by Hutchinson (*81*): "Keeping quality is at a maximum in bread made from good flour of ample gassing power, good gluten content and quality with correct absorption, dough manipulation and fermentation. Such bread will benefit little if at all in keeping quality through the addition of any of the many substances and proprietary articles which have been recommended from time to time as inhibitors of the staling process."

Flour has long been recognized as a factor of primary importance to the keeping quality of bread. The observation has frequently been made that weak flours of low protein content will produce bread which is markedly inferior in keeping quality to bread made from high protein flours. Steller and Bailey (*82*) compared four flours ranging in protein content from 9.6 to 12.6 percent. They found that bread baked from the high protein flour did not stale as rapidly nor reach as high a degree of staleness as did the bread made from the low-protein flour. Staling was not strictly a linear function of the protein content, indicating that protein quality enters into the staling reaction. Thomas (*83*) has also observed that protein content does not constitute a governing factor in the rate of bread staling. Any factor, therefore, which affects either protein content or protein quality has an indirect effect upon the keeping quality of the bread. When it is recalled that wheat variety, climate and soil conditions all influence wheat protein content and quality, the complexity of the problem becomes apparent. The conditions of bread storage were found to have a marked effect upon the staling rate. Thus bread stored at 42° C. for 96 hours was not as firm as bread stored at 11° C. for only 24 hours.

Of the various other ingredients, rye flour in proportions of 5 to 15 percent has been reported by Alsberg (*49*) to exert a slight improving effect upon keeping quality. The same author also recommends that not too much yeast be used. Milk has been found to exert a favorable effect upon the keeping quality of baked goods by Stamberg and Bailey (*84*) Platt and Powers (*68*), Glabau (*85*), Alsberg (*49*), Hutchinson (*81*) and others. The use of small amounts of glycerin has been stated by Leffingwell and Lesser (*86*) to improve the texture of bread and to aid in prolonging the product's freshness. Lecithin has been shown by Cook (*87*) to reduce the rate of moisture loss in bread.

The effects on bread keeping quality of various sugars, dextrines, starches and malt extract have been studied by numerous investigators. The use of arabinose and xylose as staleness retarding agents is the subject of two patents (*88, 89*). Such sugars as glucose, fructose and sucrose have variously been reported to have a desirable effect upon bread softness. Thomas (*83*) found that sugar in amounts of 2 to 4 percent pro-

duced a slight retarding effect on the staling rate. However, Bailey (*74*) had earlier failed to confirm claims that invert sugar and dextrinized starch acted to inhibit the staling rate. On the other hand, malt extract was found by him to exert an improving action which was subsequently attributed by Sandstedt and co-workers (*90*) to amylase action on starch, whereas Brooks (*91*) thought the hygroscopic nature of malt sugar accounted for its moisture-retaining effect. Kuhlman and Balasheva (*92*) report the descending order of carbohydrates with respect to their effectiveness as staleness retarding agents to be: maltose sirup, glucose sirup, dextrine, beet sugar, maltose, glucose, soluble starch, potato starch.

The staleness retarding effect of soy flour has been confirmed by a number of investigators. Thus Steller and Bailey (*82*) found that an addition of 1.5 percent soy flour retarded staling. A similar observation had previously been made by Straub and Hirsch (*69*). Hafner (*93*) has stated that soy flour, when used in increments of 5 to 10 percent, reduces the rate of moisture loss from the crumb and also lowers the rate of interchange of water between the starch gel and the gluten in the crumb.

Shortenings, especially of the modern improved types, have been shown to enhance the keeping quality of bread. Carlin (*94*) has reported that the influence of fats on the keeping quality is a progressive effect and is continuous at all precentages common to modern bread formulation. Loaves containing 6 percent shortening will be found to possess superior keeping quality when compared to loaves of lower shortening content. In like manner, loaves containing 3 to 4 percent shortening will excel loaves to 1 to 2 percent shortening content if tested for keeping quality after 72 to 96 hours storage time. Alsberg (*49*), Platt and Powers (*68*), Hutchinson (*81*) and others have reported on the favorable effect of shortening on the tenderness of crumb.

Schoch and French (*96*), investigating the effect of various bread ingredients on the staling of 50 percent defatted wheat starch pastes, found that the addition of 2 percent oleic acid markedly reduced the swelling power, amounts of solubles, and iodine affinity of the pastes even in their fresh states and suggest that a mono- or diglyceride would have a similar action. Shortening itself had little effect.

In recent years several so-called anti-staling or bread softening agents have been introduced whose principal function is to retard the firming of the bread crumb. Bread containing such substances in small percentages does possess a softer crumb and hence tends to maintain its fresh characteristics for a longer period than does untreated bread. The two main types of softening agents include the mono- and diglycerides and the

polyoxyethylene monostearates. Both of these types of products have been used extensively by bakers, although their use has not met with universal approval. They have been described by Carlin (*94*) and Favor and Johnson (*96*), respectively.

One point which requires to be kept in mind regarding some of the adjuncts mentioned above is that they may also produce some undesirable effects in addition to their favorable effects. Therefore their use requires close control to prevent possible deleterious effects from nullifying or overshadowing any improvement in keeping quality which these materials may produce.

Dough Treatment. The manner in which dough is made and the consistency of the dough have long been regarded as factors influencing the keeping quality of the resultant bread. It has been reasoned (*49*) that anything which increased the water content of the dough within practical limits had a favorable effect upon the keeping quality of bread. Thus slack doughs have been recommended for prolonging freshness by Hutchinson (*81*) and Garnatz and Kornreich (*97*). Optimum high speed mixing is also held to improve keeping quality. The sponge-dough method is recommended over the straight dough method by Alsberg (*49*) and Kent-Jones (*19*). On the other hand, Hutchinson (*81*) has found that short-time processes frequently gave bread of better keeping quality than did longer straight-dough and sponge-dough systems.

Optimum fermentation under accurately controlled time and temperature conditions has been found to contribute significantly to the keeping quality of bread. The general recommendation is to have the temperature as low as possible and to use the normal amounts of yeast (*98*). Alsberg (*49*) suggests that fermenting the dough at 71.6 to 78.8° F. for as long a time as is consistent with gluten strength will increase the bread's keeping quality. On the other hand, Hutchinson (*81*) has found that fermentation temperature is secondary in importance to optimum fermentation. He points out that while low temperatures reduce the risk of incorrect fermentation, bread of excellent keeping quality is obtainable from shorter fermentations conducted at higher temperatures. The important point to consider is that each type of flour be given the kind of fermentation treatment that is optimum for it. The addition of 3.0 percent sour dough has been found by Bailey (*74*) to have a retarding effect upon bread staling.

There appears to be little agreement about optimum baking conditions. Alsberg (*49*) advocates slow baking at relatively low temperatures to avoid excessive moisture loss. The same view is supported by Katz (*99*) who also cautions against overbaking. Pelshenke (*100*) recommends high initial temperatures and a long baking period at lower temperatures

to ensure good crust formation which prevents loss of moisture. Garnatz (*101*), on the other hand, favors a moderate temperature in the early stages of baking, with a limited amount of moist steam, followed by higher temperatures. European experience indicates that, as a rule, the thicker the crust formed during baking, the longer does the bread retain its freshness.

Many of the recommended ingredients and procedures whose aim is to retard the staling process of the bread crumb tend to have an accelerating effect upon crust staling. Thus crust staling is decreased by low fermentation temperature, low proportion of yeast, low absorption, and low salt addition, all of which are factors that exert an unfavorable effect upon crumb staling. The influence of wrapping on crust staling has been indicated above. In general, emphasis is placed upon crumb freshness and the crust is relegated to a secondary position.

Cathcart (*48*) has summarized in a tabular form the effect of various factors on the staling rate of bread crumb, as shown in Table 111.

While considerable scientific and technological research has been carried out on bread, ingredients, manufacturing methods and storage conditions in an effort to solve the bread staling problem, progress thus far has been rather slow. This has been due mainly to our inadequate understanding of the staling process itself, to the lack of uniformity in the chemical, physical and organoleptic methods of evaluating staleness, and to the inherent complexity and variability of flour and dough. Geddes and Bice (*50*), in considering the direction of future research on the staling problem, outline the following program:

"One of the prime requisites for future research is a clear-cut understanding of what constitutes staleness in a loaf of bread from the standpoint of consumer acceptability. The next step would appear to involve the standardization of methods so that the results of various workers may be comparable. While the complexity of flour presents an obstacle, the use of synthetic flours affords a means of studying individually the effects of the various flour constituents, independent of variations in the properties of the other flour components. Additional studies should be conducted on the effects of successive additions of components and adjuncts in the bread formula, starting with simple mixtures. While considerable progress has been made on the fundamental changes occurring in starch pastes during staling and the effects of adjuncts on such systems further basic research is merited. Such research is certainly needed in the case of proteins where only a few experiments have been undertaken to elucidate the possible role of gluten in staling. One of the most important and at the same time least studied phases of bread staling is the change in flavor. In this connection it would be desirable to know what factors are responsible for the desirable flavor of bread and what causes the change in flavor with passing time."

TABLE 111. EFFECT OF VARIOUS FACTORS ON THE RATE OF STALING OF BREAD CRUMB

Factor	Effect on the: Rate of practical staling	Effect on the: Rate of change of starch	Reported by
Heat, 60° C.	Decreases rate	Decreases rate	Katz, others
Refrigeration, −22° C.	Decreases rate	Decreases rate	Cathcart and Luber
Refrigeration, −35° C.	Greatly decreases	Greatly decreases	Cathcart and Luber
Wrapping	Decreases rate	No effect	Boussingault, Katz, others
Flour (large % and high quality gluten)	Decreases rate	No effect	Alsberg, Hutchinson, Katz, others
Rye flour (5%-10%)	Slightly decreases	Little effect	Alsberg, Banfield
Yeast	?	No effect	Alsberg
Milk	Decreases rate	No effect	Alsberg, Hutchinson, Katz, others
Normal % salt	Decreases rate	No effect	Alsberg
Gelatinized starch, etc.	Slightly decreases rate	No effect	Alsberg, Hutchinson, Bailey, Katz, Jago and Jago, Whymper
Shortening	Decreases rate	No effect	Alsberg, Hutchinson, Katz
Malt Extract	Slightly decreases	No effect	Alsberg, Hutchinson, Bailey, Whymper
Sour dough	Slightly decreases	No effect	Bailey
Protective colloids	Slightly decreases	No effect	Bailey, Hutchinson
Gelatin	Slightly decreases	No effect	Hutchinson
Glucose	Slightly decreases	No effect	Hutchinson, Bailey, Whymper
Maltose and glucose sirup	Slightly decreases	No effect	Kuhlman, Balasheva
Invert sugar	Slightly decreases	No effect	Bailey
Glycerin	Slightly decreases	No effect	Bailey, Whymper
Soy flour	Slightly decreases rate	Very slightly decreases rate	Hutchinson, Steller, Bailey
Whey	Slightly decreases	No effect	Hutchinson
Egg whites	Slightly decreases rate	Probably no effect	Banfield
Slack dough	Decreases rate	No effect	Hutchinson
Optimum high-speed mixing	Decreases rate	No effect	Alsberg, Hutchinson
Proper fermentation	Decreases rate	No effect	Alsberg, Hutchinson, Katz
Sponge fermentation	Decreases rate	No effect	Alsberg, Kent-Jones
Long fermentation	Decreases rate	No effect	Kent-Jones, Katz
Proper handling	Slightly decreases rate	No effect	Alsberg, Hutchinson, Katz
Proper baking	Slightly decreases rate	?	Alsberg, Hutchinson, Katz
Proper cooling	Decreases rate	No effect	Alsberg

Until such time as this projected program materializes and its results become available, the following general recommendations will prove helpful in producing a palatable loaf of good keeping qualities: Use flour containing a large amount of high-quality protein. The formula should include liberal amounts of dry milk solids, shortening and sugar, normal amounts of salt and yeast, and some malt extract and moisture-retaining agent. The dough should be mixed by high-speed mixing and kept medium slack. Optimum fermentation and baking are important. The finished bread should be cooled rapidly and adequately and then wrapped.

BREAD FAULTS

Bread faults may be divided into two categories, namely those which originate from poor quality ingredients, and those which arise from faulty production. Since bread faults may be the result of several factors in either or both categories, it is generally more convenient to list them according to broad classifications and indicate the various possible causes. Pelshenke (*101a*) recently made the very succinct observation that "every baking plant encounters as many bread faults as it deserves." In other words, it is possible to eliminate every bread fault through close attention to both the quality of ingredients and the production procedures employed. This is not to deny that it is frequently a very difficult matter to arrive immediately at the correct diagnosis of a bread fault and to remove its cause. However, the occurrence of bread faults will be far less frequent and their nature less severe if proper precautions are taken at all times to ensure that high quality ingredients only are used, that errors in the formula are avoided, that proper time, temperature and humidity controls are provided and adhered to throughout the dough and baking stages, and that all equipment is kept at optimum operating efficiency.

In the following pages are enumerated certain broad classes of bread faults, together with indications of their probable causes. A very complete listing of causes of bread faults, with suggested corrective measures, has been compiled by Vander Voort (*102*). Wihlfahrt (*103*) and Gerhard (*104*) have also provided brief, but very useful discussions on this subject.

TABLE 112. BREAD FAULTS

EXTERNAL FAULTS

Lack of Volume:

1. Immature or green flour
2. Wrong kind of flour for type of bread
3. Insufficient absorption

4. Insufficient yeast
5. Incorrect yeast handling, e.g., chilling or heating of yeast while dissolving in water
6. Too much salt
7. Excess of diastatic activity
8. Overmixing or undermixing
9. Over-fermented or under-fermented doughs
10. Too low a dough temperature
11. Chilling of dough during fermentation or proofing
12. Insufficient pan proof
13. Improper humidity conditions during proofing and baking
14. Insufficient dough weight for pan size
15. Excessive oven temperature

Excessive Loaf Volume:

1. Insufficient salt
2. Over-aging of dough
3. Overproofing
4. Too much dough for pan size
5. Low oven temperature

Pale Crust Color:

1. Insufficient sugar
2. Deficiency of diastatic activity
3. Too high a fermentation temperature
4. Crusting of dough during proofing
5. Dry proof box
6. Over-aging of dough
7. Low oven temperature
8. Low top heat in oven
9. Too short a baking period

Crust Color Too Dark:

1. Excessive sugar in formula
2. Immature or young dough
3. Too high an oven temperature
4. Excessive top heat in oven
5. Over-baking
6. Oven atmosphere too dry

Crust Blisters:

1. Improper mixing
2. Young dough
3. Carelessness during molding
4. Excessive steam in proof box
5. Excessive oven steam leading to condensation

Excessive Crust Thickness:

1. Insufficient sugar
2. Insufficient milk in formula
3. Deficient diastatic action

4. Crusting of dough during proofing
5. Over-aged dough
6. Low oven temperature
7. Too long a baking period

Shell Tops:

1. Immature flour
2. Deficiency in diastatic action
3. Excessively stiff dough
4. Immature or young dough
5. Insufficient pan proofing
6. Dry oven steam
7. Crusting of dough during proofing

Absence of Break and Shred:

1. Weak flour
2. Too high an absorption
3. Excessive diastatic action
4. Doughs too young or too old
5. Inadequate proofing
6. Excessively hot oven
7. Dry oven

INTERNAL FAULTS

Gray Crumb Color:

1. Excessive amount of malt
2. Too long a proof
3. Over-aged doughs
4. High fermentation temperatures
5. Low oven temperature

Streaky Crumb:

1. Improper blending of flour
2. Improper dough mixing
3. Excessive dusting flour
4. Dough crusting during intermediate proof
5. Too much divider oil
6. Improper moulder setting
7. Pick up of scrap dough during make-up
8. Crusting of sponge during fermentation
9. Excessive pan grease

Coarse Grain:

1. Weak flour
2. Extremely stiff doughs
3. Too high an absorption (slack doughs)
4. Over-mixing
5. Young doughs
6. Improper moulding
7. Insufficient dough weight for pan size
8. Oven temperature too low

Poor Texture:

1. Extremely stiff doughs
2. Improper mixing
3. Excessive diastatic action
4. Over-aged doughs
5. Crusting of sponge or dough during fermentation
6. Dough crusting during intermediate proof
7. Excessively high proof box temperature
8. Over-proofing
9. Insufficient dough weight for pan size
10. Oven temperature too low

Poor Flavor:

1. Low quality ingredients
2. Insufficient salt
3. Improper storage conditions
4. Unbalanced formula
5. Over-fermentation
6. Under-fermentation
7. Under-baking
8. Unsanitary plant conditions
9. Use of old trough and pan grease
10. Presence of external odors.

Poor Keeping Qualities:

1. Unbalanced formula
2. Insufficient milk solids
3. Insufficient sugar content
4. Poor quality ingredients
5. Improper mixing
6. Over-fermentation
7. High dough temperature
8. Excessive proofing
9. Low oven temperature
10. Improper bread cooling conditions

Holes in Bread:

1. Immature flour
2. Weak flour
3. Insufficient salt
4. Improper mixing
5. Excessively stiff doughs
6. Over-aged doughs
7. Young doughs
8. Crusting of sponge or dough
9. Improper moulding
10. Inadequate intermediate proof
11. Excess dusting flour
12. Excess divider oil
13. Too high a proofing temperature
14. Insufficient oven steam
15. Flashy oven.

CHAPTER XXI

PHYSICAL AND CHEMICAL TESTING METHODS

The fact that certain acids increase the swelling capacity of gluten, the degree of swelling depending in a large measure upon the intrinsic gluten characteristics, forms the basis of several qualitative testing methods. Thus one of the simplest measurements of quality is the determination of the increase in viscosity of flour-water suspensions obtained by the addition of lactic acid. So-called strong flours yield a great increase, whereas weak flours yield a small increase in viscosity, so that this method affords a ready means for differentiation. The increase in viscosity is due to the swelling of the gluten under the influence of the lactic acid, more water being absorbed by the gluten in its presence than in its absence. Upson and Calvin (*105*) studied the effects of acids on washed gluten, their principal interest being to observe the effects of different acids. Gortner and Doherty (*106*) applied the method of Upson and Calvin to the gluten obtained from flours of different strengths and were the first to observe the different swelling capacities of strong and weak flours. Berliner and Koopman (*107*) devised a simple method for determining the swelling capacity of gluten, known as the Berliner-Koopman method, which is extensively used in European mill and baking laboratories. In this method wet gluten of a given weight is cut into small pieces which are then added to a measured volume of 0.1 normal lactic acid in a special conical flask possessing a long graduated neck. The neck is stoppered and the flask inverted so that the gluten settles in the neck and its initial volume may be read. The flask is then set aside at room temperature and periodic readings of the gluten volume increase are taken, with the final reading being made after 2.5 hours. The increase in volume exhibited by 1 g. of gluten after 2.5 hours is termed the "specific swelling factor." If properly carried out this method appears to give results which are fairly closely correlated with results obtained by the baking test. Although the method was criticized by Fisher and Halton (*108*), Pelshenke (*109*) has reported results obtained with European wheats which show fairly good correlation with other criteria of gluten quality as may be seen from the following table:

TABLE 113. SWELLING NUMBER OF GLUTEN FROM SEVERAL FLOURS

Sample	Swelling number	Loaf volume cc.	Dry gluten %	Doughball min.
Bankut 66	25.0	417	12.8	121
Bankut 1014	23.6	411	13.3	91
Szekacs 1055	20.0	401	11.5	71
Bankut 121	17.6	392	13.9	41
Hatvan 3490	14.4	358	11.2	31
Bankut 1201	12.8	396	13.2	37
Hatvan 1153	8.6	344	11.0	26
Hatvan 1119	1.0	318	12.9	23

It will be noted that with a decrease in the swelling number, there is a corresponding decrease in loaf volume in all instances but one. The dry gluten content of the different flours does not exhibit great variability so that the differences in quality are not measured by that factor. The figures in the last column are values obtained by the so-called "wheat-meal fermentation time test" developed by Pelshenke (*109*) and independently also by Cutler and Worzella (*110*) in this country. In this method dough balls are prepared from 5 g. of finely ground wheat meal with an addition of yeast and water. The balls are then placed in small beakers filled with water at controlled temperature and allowed to ferment. The results are expressed in terms of minutes required for the balls to burst under the influence of the developing carbon dioxide. The method measures the gas-holding power of the gluten, which is affected by its quality as well as its quantity. Glutens of good quality hence give higher doughball times than do glutens of poor quality. In the above table it will be noted that the doughball times correlate well with the gluten swelling number and also with loaf volume. The doughball method has been critically examined by Wilson, Markley and Bailey (*111*) and Swanson (*112*) who found that its results are markedly affected by a variety of external influences and that its performance requires great attention to details.

Zeleny (*113, 114, 115*) developed a sedimentation test which in several respects is similar to the Berliner-Koopman method. Both methods are based on the swelling effect produced by lactic acid treatment of flour gluten, the main difference between the two tests being that the Berliner-Koopman method is carried out on washed gluten, whereas Zeleny's sedimentation test utilizes flour. Basically, the sedimentation test is based on the principle that when a suspension of flour in water is treated with lactic acid under certain controlled conditions, the gluten particles swell enormously and the swollen gluten settles to the bottom of the suspension. If the suspension is treated with the acid in a calibrated glass cyl-

inder, the rate of settling of the swollen gluten may be readily observed and measured. The test requires only 4 grams of flour, on a 14 percent moisture basis, which are placed in a 100 ml. glass-stoppered graduated cylinder, with the addition of 50 ml. of distilled water and 25 ml. of dilute lactic acid. The contents of the cylinder are then mixed by inverting the stoppered cylinder ten times and the volume of the sediment read exactly 5 minutes after the cylinder has been placed in an upright position. The level at which the swollen gluten will settle will depend upon

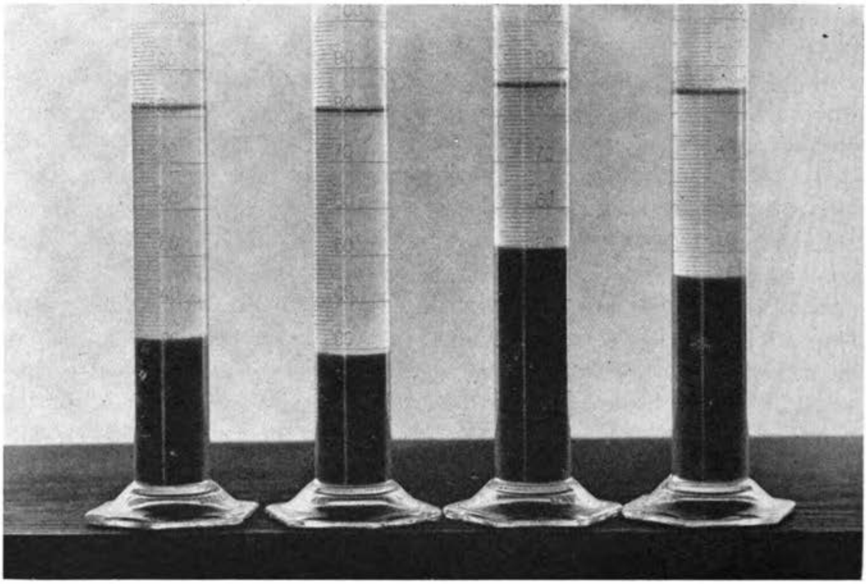


FIG. 91—Illustration of sedimentation test at the time the final readings are taken. The second cylinder from left represents a typical flour of poor bread-baking quality and the third cylinder from the left represents a typical flour of superior bread-baking quality.

(1) the quantity of gluten in the flour, and (2) the extent to which the gluten is swollen which, in turn, is determined by the quality of the gluten. Sedimentation values in ml. of solid phase after 5 minutes of settling can be expected to range from 20 or less for low protein flour of very inferior bread-baking quality to 55 or more for high protein flour of superior bread-baking quality. Typical results of the test are shown in Figure 91. In this example, the second cylinder from the left represents a typical flour of poor quality and the third cylinder from the left represents a typical flour of superior bread-baking quality. The results of the wheat sedimentation test show a high correlation with the bread-baking quality of wheat as judged by the loaf volumes and

baking scores of bread and appear to be a better index of bread-baking quality than the farinograph test widely used in evaluating flour.

PHYSICAL DOUGH TESTING

The objective measurement of the physical properties of dough has received extensive study within the past three decades from which have developed a number of sensitive instruments designed to yield records of the mixing, absorption, fermentation and oxidation characteristics of flours. By correlating the data obtained by means of these various instruments with the results of baking tests it is frequently possible to arrive at dependable conclusions concerning the baking quality of the flour under consideration. The test data can then be used by the baker as a guide to the most advantageous mixing, fermentation and diastatic treatments of the flour in the bakery.

RECORDING DOUGH MIXERS

Among the important operations in bread production is the mixing of the dough. This process performs the twofold task of blending the ingredients and of developing the gluten. Proper gluten development is essential for the retention of the carbon dioxide gas produced during subsequent fermentation. Hence, the degree of aeration ultimately obtained in the finished product is to a large measure determined at the mixing stage. Thorough blending of the ingredients is quickly attained, whereas gluten development requires more mixing. The point of optimum gluten development is difficult to assess under practical plant conditions. It varies with the type of flour used and is further influenced by such additional factors as mixing temperature, mixing speed, amount of absorption, type and amount of additional ingredients, etc. Every flour has an optimum mixing time at which it yields doughs possessing superior properties, especially with respect to their machineability and their ability to produce loaves of optimum physical characteristics. Physical dough testing apparatus of the recording mixer type, such as the farinograph and the mixograph, and the recording watt-meters and consistometers, such as the mixatron, have proved valuable in assessing the mixing characteristics of a given flour.

The Mixograph. The mixograph is a miniature type of high speed dough mixer first developed by Swanson and Working (*116, 117, 118*). In its modern version, the mixograph is enclosed in a thermostatically controlled cabinet to prevent changes in temperature while the doughs are being mixed. In addition, a humidifier is provided to hold the humidity within the cabinet at a uniform level. The mixing effect is obtained by four vertical pins attached to a rotating mixing head which

revolve through the dough in a planetary motion around three fixed pins. As the gluten develops, a gradually increasing amount of force is required to push the revolving pins through the dough. This increased force imparts a twisting motion to the mixing bowl which is placed in the center of a lever system. The degree of twist produced is measured and recorded by means of a stylus on a chart traveling at a uniform rate of speed. A hypothetical curve or mixogram is shown in Figure 93 (*119*) which also illustrates the method used in securing the various curve

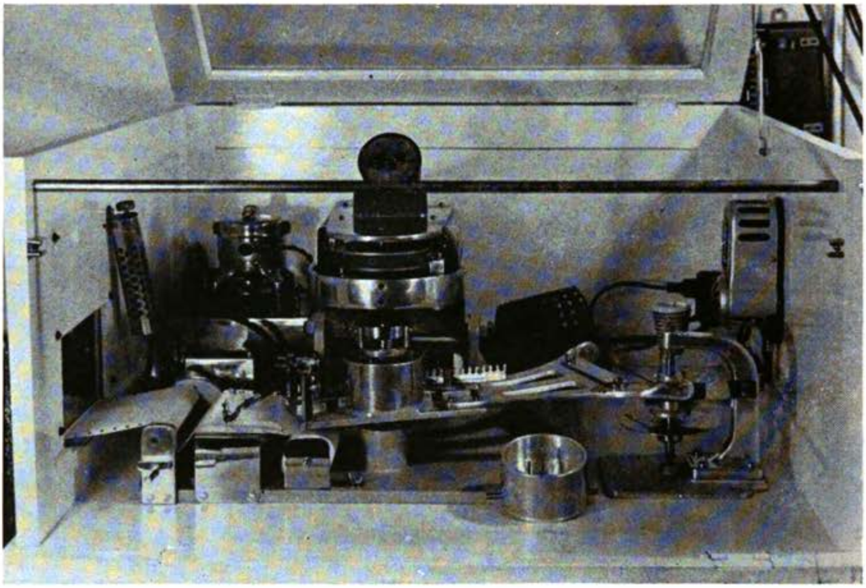


FIG. 92—The mixograph.

measurements. A line is drawn through the center of the curve to represent the actual shape as closely as possible. The distance from the start of the curve to its peak D constitutes the stage of dough development, i.e., that part of the curve that is indicative of the period during which dough formation takes place. The range of dough stability during mixing is indicated by line B which covers the distance between the two points where the line drawn through the curve peak parallel to the base cuts the edge of the curve. Curve height C is commonly thought to be interrelated with the flour absorption and protein content, the height tending to be reduced with increased absorption and increased with increased protein content. Other measurements of curve properties which some workers have felt possess significance include the dough development angle, or the angle between the ascending and descending sections of the curve;

and the dough weakening angle which is the angle formed with the tangent drawn at the peak of the curve and the line paralleling the general slope of the curve beyond the peak. The greater this angle, the more rapid the breakdown, and vice versa. Curve width has also been studied in relation to other quality factors, but with little apparent success. A mixogram will generally disclose the time required by a flour for optimum dough development and will hence quite clearly differentiate between flours that require relatively little time and those that need a longer time to achieve optimum dough development (*120*). It also will

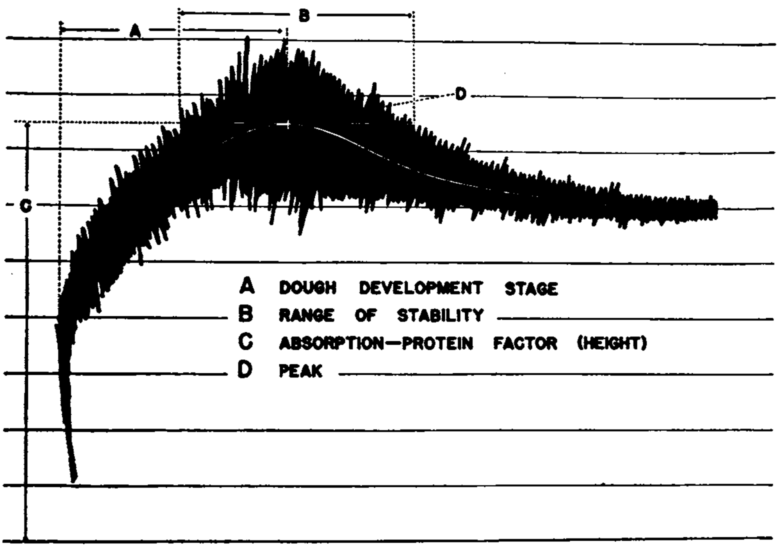


FIG. 93—Specimen curve illustrating interpretation of mixogram.

show the tolerance toward over-mixing possessed by a flour. It has not been definitely established whether the degree of the descending slope actually denotes a weakness in the flour, but it does suggest that flours with a great dough-weakening angle may easily be over-mixed. Johnson, Swanson and Bayfield (*121*), in a study of the relationship of mixograms to baking results, reached the conclusion that the greatest value of mixograms was the supplementary information they provided regarding mixing requirements, mixing tolerance and varietal patterns that may or may not be related to the true baking value of the flour. Sensitivity of a flour to over-mixing was correlated with the decrease in the quality of the baked product if the dough was over-mixed.

The Farinograph. The Brabender farinograph, which represents an improved version of an apparatus developed by Hankoczy of Hungary, has probably received wider acceptance among cereal chemists than any

other experimental dough testing machine. The apparatus incorporates a high speed mixer and is so designed that the force required to turn two helical, spiral blades through a dough is measured with a dynamometer system which, in turn, is connected to a recording mechanism that produces a graph showing a record of the mixing process. The apparatus, of which a schematic diagram is shown in Figure 95, consists of the following essential parts: A water-jacketed mixing bowl (1), which may be had in two sizes, for 300 g. flour and 50 g. flour, is connected to a freely swinging

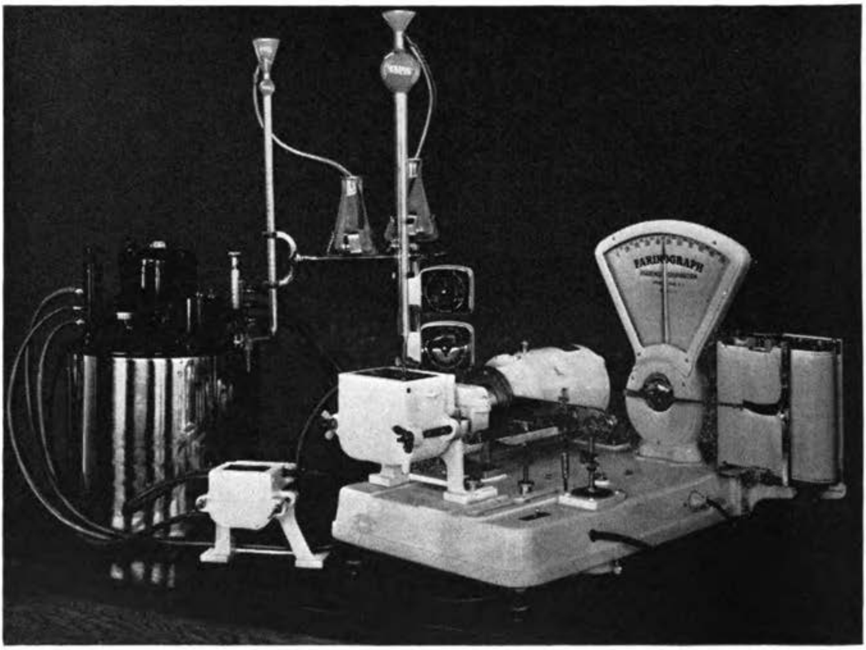


FIG. 94—The Brabender farinograph.

dynamometer (2) which is part of a synchronous constant-speed motor. The dynamometer is fitted with high-grade bearings (3). The movements of the registering dynamometer are transferred by a lever system (4), which is provided with an oil damper (5), to a scale system (6). The latter is connected to a recording system consisting of a kymograph and inked stylus which produces the chart or farinogram. The mixing bowl and oil damper are maintained at a constant temperature by circulating water from the thermostat (8) which contains electrical heating elements controlled by a thermoregulator (10). A special burette (11) is used to measure the amount of water used for preparing the dough.

The farinogram is traced on a band of paper on which there is a

printed scale. The curved vertical lines of the cross section pattern are so spaced that the chart moves the distance from one line to the next in one half minute. There are 50 horizontal lines scaled arbitrarily to cover a range of 0 to 1000 so-called Brabender Units (B.U.) extending in the vertical direction. Since these lines are evenly spaced, each represents 20 units, and they are used to indicate the consistency of the dough. In the schematic farinogram shown in Figure 96, the height of the curve centers on the 500 B.U. line, but this varies with the protein content of the flour and the amount of absorption water used for making the dough.

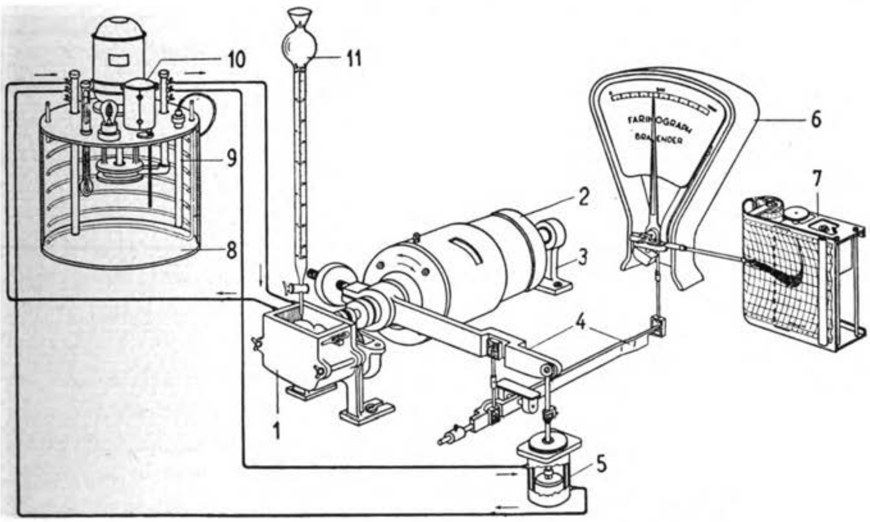


FIG. 95—Schematic diagram of the Brabender farinograph.

The significant measurements taken on a farinogram are: (A) the dough consistency; (B) the dough development time, or optimum mixing time; (C) the mixing stability or mixing tolerance; (D) the elasticity or distensibility of the dough; and (E) the weakening of the dough. By taking a consistency of 500 B.U. as a standard, it is possible to closely measure the optimum absorption of a flour by determining the amount of water it requires to attain this consistency (*122*). The dough development time (B), which is a measure of the time needed for the curve to reach its peak or point of maximum dough consistency, varies with different flours and is indicative of gluten quality, strong flours generally giving a longer development time than weak flours. The mixing tolerance (C) of a dough is indicated by that portion of the curve in which there is no marked change in consistency on sustained mixing. The longer this portion of the curve in terms of time units, the greater is the

mixing tolerance possessed by the flour. Since mixing tolerance is one of the principal flour characteristics in which the baker is interested, this determination represents an important application of the farinograph. The band width (D) was formerly assumed to indicate the actual elasticity of the dough, an interpretation that is no longer widely accepted (*118*), since it has been shown by Markley and Bailey (*123*) that the width of the line is a function of the mobility of the dough. All doughs eventually break down on sustained mixing which, in the farinogram, is indicated by the point at which the curve starts to descend. The sooner

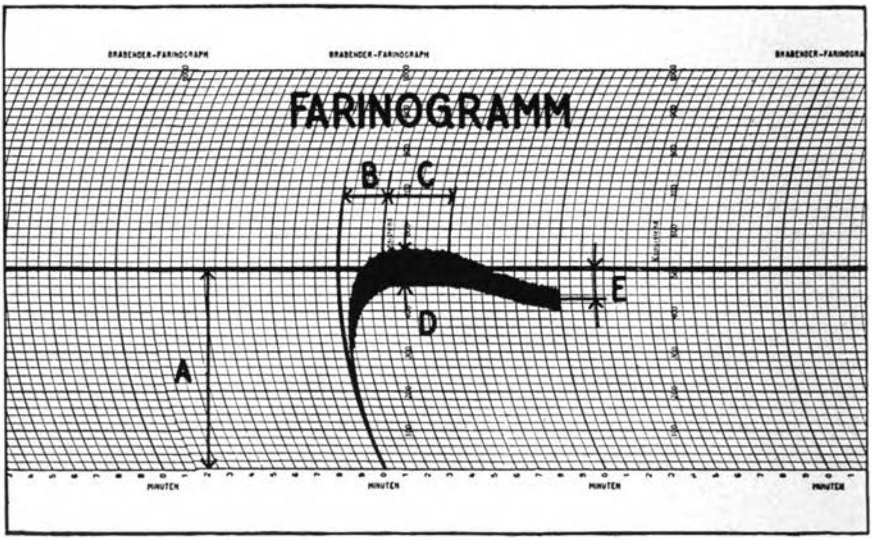


FIG. 96—Specimen curve illustrating interpretation of farinogram.

this break occurs, the less fermentation and mechanical abuse the flour can generally withstand.

Hoffman and co-workers (*124*) have applied the farinograph to the evaluation of the baking properties of nonfat dry milk solids. It has long been observed that, under shop conditions, nonfat milk solids of poor baking quality produce soft, slack doughs, prolonged proofing time, and poor oven spring. The bread containing such milk solids has a small loaf volume and poor crumb and texture. There apparently exists a definite correlation between "baking quality" of milk solids and dough consistency. In the procedure developed by these workers, the absorption is determined of a mixture of equal parts of spring wheat flour and nonfat dry milk solids after 10 to 14 minutes of mixing to allow time for any softening action of the milk solids on the gluten to take place.

Knowing the absorption of the flour itself, the absorption due to the milk solids can be readily computed. The absorption as measured by this procedure comprises two factors: the actual physical absorption of water by the dry milk plus a measure of its softening action. It was found that nonfat milk solids of satisfactory baking quality give absorption values of 70 percent or higher, while milk solids of low quality give values of 65 percent or lower.

An auxiliary aid to the farinograph is the valorimeter which is a kind of large slide-rule into which farinograms can be placed for calculating a numerical value indicative of the "strength" of the flour on the basis of a logarithmic scale. These valorimeter values are particularly useful in flour blending operations since they facilitate the proportioning of flours of different strengths to arrive at the desired uniform strength of the blend.

Recently the introduction of a new two speed farinograph has extended the applicability of this apparatus also to the testing of cake, pastry and soft wheat flours in general (*125*). It had previously been observed that no meaningful results could be obtained when soft wheat flours were mixed at high speed. Strong abuse of the soft gluten strands in cake flours caused their tearing and a breakdown in the dough which tended to obscure the gluten development itself, and the picture thus obtained constituted a summation of the rates of gluten development and gluten breakdown, whereas the characteristic it was desired to have measured was development alone. In the new two speed farinographs the normal speed of 60 r.p.m. is for bread flours, while the low speed of 30 r.p.m. has been found to be most suitable for soft wheat flours. Two methods are currently in use for testing soft wheat flour by this instrument. In the first, a flour and water dough is mixed to yield a consistency of 500 B.U. using the low speed of the machine. The curves obtained are similar to those which result on bread flours at the higher speed and can be interpreted on the basis of (a) the rate of gluten development, (b) the length of time the curve stays up without breaking down, and (c) the shape and speed of the breakdown section in the curve. In the second method the flour is given a fixed absorption of nearly 70 percent to produce a very soft dough. This requires that the larger mixer be used and that the farinograph be adjusted to its most sensitive setting. The curve development is naturally much slower, taking about 60 minutes as compared to the 10 to 20 minutes needed for the other method. This second method has the advantage of permitting the operator to detect quite minute quality differences between flours. Furthermore, it gives the gluten of the soft wheat flour a better chance for its true development than is possible with doughs of heavier consistency in which excessive stretching

and occasionally tearing are practically unavoidable. By the use of extremely soft doughs the second method comes much nearer to a true viscosity measurement than the first. A direct correlation is said to exist between the soft dough farinograms and pastry flour values (*125*).

In the hands of an experienced bakery technologist, the farinograph will render the following practical control services: check the uniformity of flour receipts as far as type and mixing strength or tolerance are con-

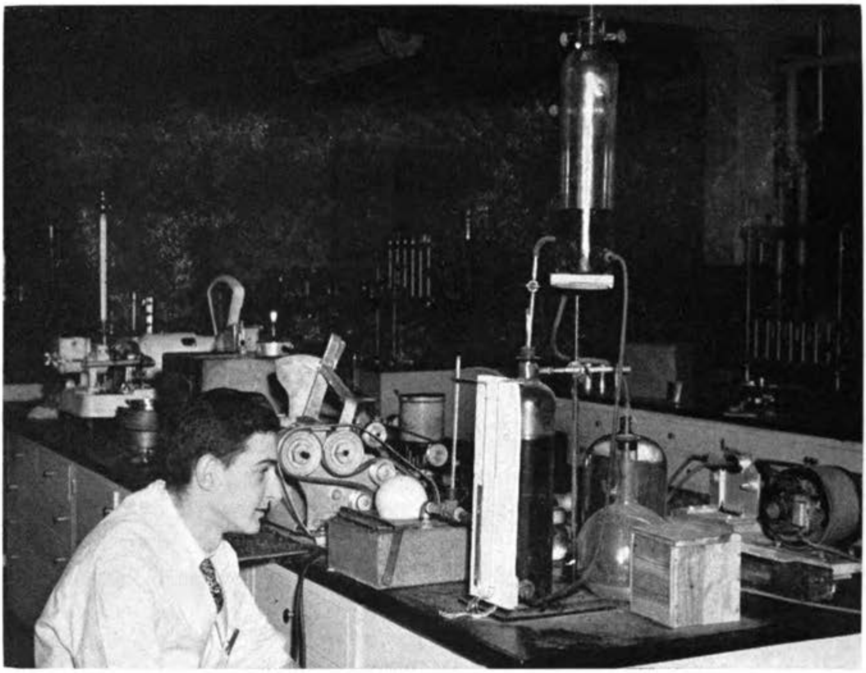


FIG. 97—View of a modified version of the Chopin extensograph in operation. (*Courtesy George Hill, Ward Baking Co.*)

cerned, these factors being revealed by the general shape of the farinogram; determine the absorption and the mixing requirements of a flour before it goes into production; assist in the blending of available flour supplies into one uniform blend of desired characteristics; check the dough consistency at various stages of production; and provide a convenient means for establishing the quality and uniformity of shipments of nonfat dry milk solids.

Extensimeter. The Chopin extensimeter or alveograph is an instrument designed to measure the extensibility and resistance to expansion of a thin sheet of dough (*19, 126, 127*). Basically, the instrument measures the pressure attained by a carefully controlled flow of air against a

dough sheet until the extended dough membrane bursts. The thin dough sheet, prepared under strictly defined conditions, is securely held between two metal plates, the upper one having a circular hole 58 mm. in diameter through which the expanding dough bubble can rise, while the lower plate is provided with a small air valve. The air valve leads to a small air chamber beneath the bottom plate which is connected with a large burette which provides the air pressure by having water rise in it and displacing the air. The air chamber is additionally connected with a manometer which, by a system of levers, records the changes in air pres-

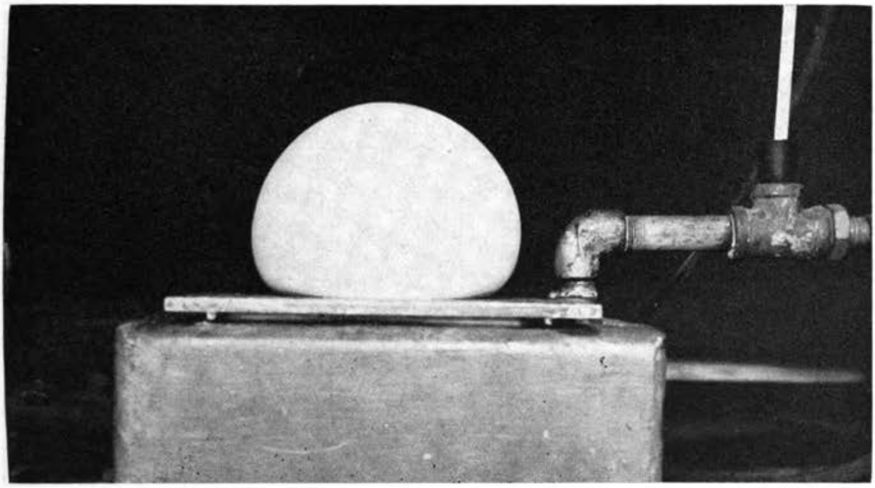


FIG. 98—Dough bubble produced by the Chopin extensograph. (*Courtesy George Hill, Ward Baking Co.*)

sure during the test in the form of a single line curve. The dough is maintained at a uniform temperature of 25° C. As is indicated by the schematic diagram of the curve obtained by the Chopin extensimeter shown in Figure 99, the resistance of the dough to expansion is greatest at the outset of the test, resulting in a steep vertical rise of the curve which reaches its optimum point P in a very short time. This pronounced pressure at the start is due to the heterogeneous arrangement of the gluten strands and their inertia. This is followed by a marked decrease in pressure as the gluten strands are forced into parallel alignment and begin to stretch and slide past each other with greater ease. This is revealed by a clearly defined decrease in the curve, which is most rapid at first and becomes more gradual until the point is reached where the dough bubble ruptures at M. The height PQ indicates the tensile strength or stability of the dough in its initial state which corresponds to the maximum resistance reached in time OQ. The following

main points in dough resistance changes are revealed by the curve: (1) maximum pressure at P, (2) medium pressure in the interval PM, and (3) least pressure at M since at this point pressure ceases due to the bursting of the dough membrane. The total volume of the bubble may be read on the large graduated burette since it corresponds to the dis-

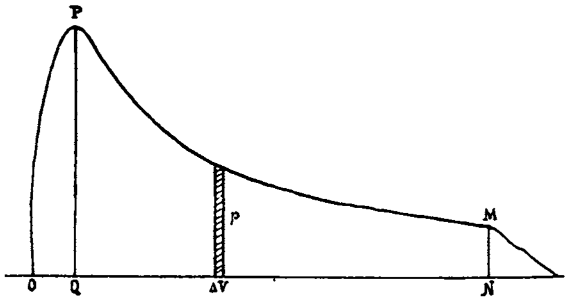


FIG. 99—Type of curve traced by the Chopin extensimeter.

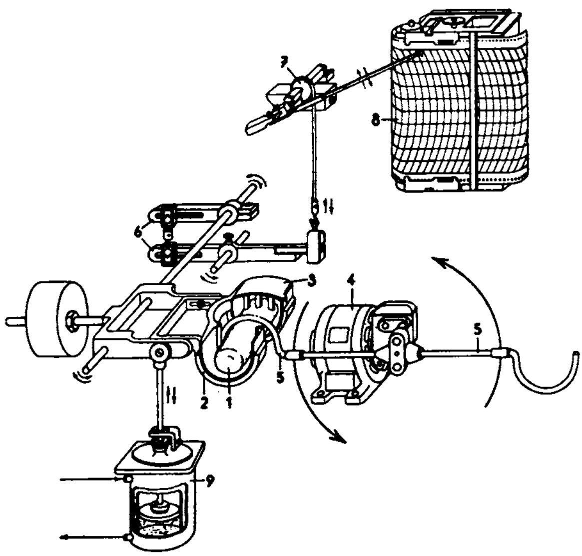


FIG. 100—Schematic diagram of the Brabender extensograph. (*Brabender Corp.*)

placed air, or it may also be determined by measuring the total area under the curve by means of a planimeter. The volume of the dough bubble is a measure of the amount of work done on the dough before rupture and is indicative of the general strength of the flour. The extensibility of the dough is shown by the line ON. Thus the curve of the Chopin extensimeter provides a fairly complete picture of dough characteristics.

EXTENSOGRAPH

Dough extensibility and resistance to extension may also be measured by the Brabender extensograph, an instrument first described by Kuhlmann (*128*) and more recently by Bailey (*118*) and Kent-Jones and Amos (*19*). The apparatus is shown schematically in Figure 100 (*118*). For the test, a dough is prepared in the farinograph to a definite consist-

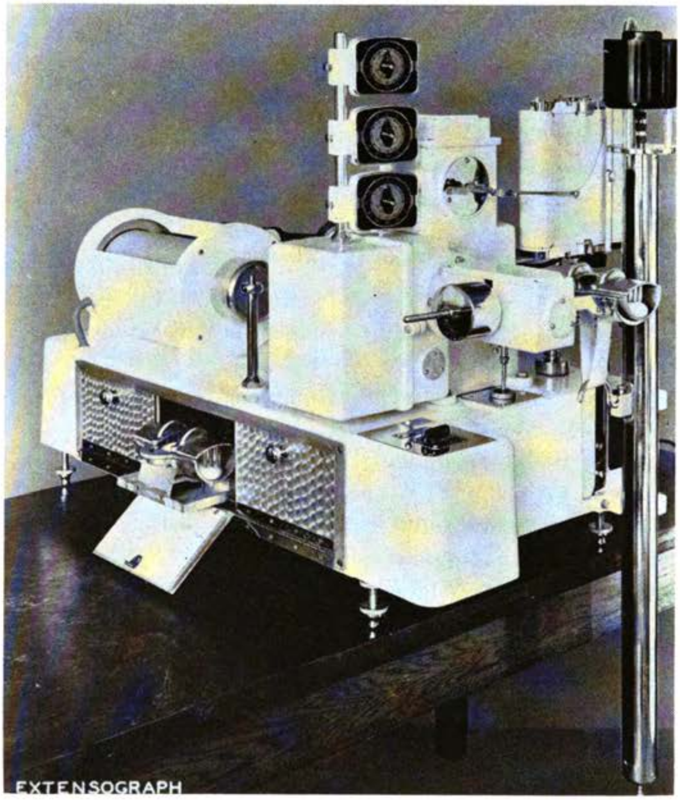


FIG. 101—Brabender extensograph. (*Courtesy Brabender Corp.*)

ency and with an appropriate mixing time. A definite quantity of the dough is then scaled off, rounded and moulded mechanically by the respective dough handling units provided with the extensograph, and then placed in the fermentation cabinet of the apparatus. After 45 minutes, the dough piece (1 in the figure), supported on a special cradle (2), to which it is securely held by clips (3) of which only one is shown in the drawing, is then engaged by an arm (5) driven by a motor (4) and stretched. In later models, such as shown in Figure 101 the stretch-

ing arm moves vertically on a guide shown at the extreme right. As the dough is stretched by the downward moving arm, force is exerted which is transferred through a system of levers (6 and 7) to the stylus which records it on a chart (8). The greater the force, the lower the point on the chart reached by the stylus. As the drive that imparts the horizontal motion to the chart is synchronized with the motor actuating the stretching arm, the distance traveled by the arm is registered in the horizontal direction on the chart.

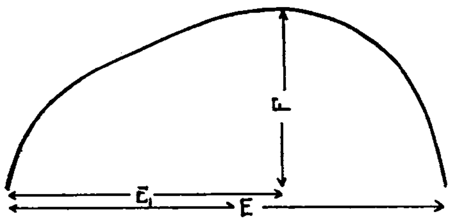


Fig. 102—Type of curve traced by the Brabender extensograph.

A typical extensogram is shown in Figure 102 (*118*) with the following constants indicated:

F = the force applied to extend the dough at constant speed of extension

E = extensibility, measured on the horizontal axis

E_1 = extension to optimum point of resistance to extension

A = area under the extensogram.

In general, the following interpretation may be placed on the curves obtained with the extensograph (*125*):

1. The greater the extensibility (E) and, at the same time, the greater the resistance to extension (F), i.e., the greater the total area (A), the better are the volume potentialities of the flour.

2. In order to attain its highest baking value, a dough must show a certain balance between extensibility and resistance to extension. The better the balance of these two factors, the better will be the texture and cell structure in the loaf. In doughs having too much extensibility and not enough resistance to extension, such a balance can be brought about by maturing agents, such as bromate. Provided the desirable balance has been determined by experience, the exact bromate requirements can be ascertained by means of the extensograph.

3. A certain height of curve (depending, of course, on the flour and the uses to which it is put) is very desirable. Such a minimum height (resistance to extension) is even more important in hearth bread than in pan bread. Some flours, although they may have been brought to a perfect balance between extensibility and resistance to extension, will not attain such a height.

4. By repeating extensograph tests on the same piece of dough, after definite intervals of time, the progress of the change in physical properties during fermentation can be observed. The graph, for instance, will reveal whether a rapid or a slow fermentation is going on in that particu-

lar dough. The extensogram will thus provide a clue as to the fermentation tolerance of the dough, as well as to its relative fermentation time.

THE AMYLOGRAPH

With the recognition of the importance of alpha-amylase activity in bread production, there arose the need for an instrument which would evaluate the baking quality of flours as influenced by amylolytic activity. This need was met with the development of a recording viscosimeter by Brabender (*129*) which he called the amylograph and which has subsequently been described in detail by Anker and Geddes (*130*), among others. This apparatus provides a continuous automatic record of the viscosity changes which occur in a flour-water suspension being subjected to a uniform increase in temperature. The viscosity tends to increase as the starch gelatinizes, while the liquefying action of alpha-amylase has an opposing effect. The height of the curve at maximum viscosity is taken as an index of amylase activity.

The amylograph is a torsion viscosimeter consisting of a cylindrical tinned-brass bowl of 500 ml. capacity in which the flour or starch suspension is placed for heating at a constant rate which results in a temperature increase of about 1.5° C. per minute. The bowl contains eight fixed vertical pins and is rotated at 75 r.p.m. in an electrically heated bath by a synchronous motor. The same motor also operates the kymograph and the device that controls the temperature increase. The head, which replaces the customary viscosimeter bob, consists of seven metal pins attached to a circular disk which, in turn, is attached to a free-moving central shaft. The upper end of the shaft is connected to a coiled-wire spring which is fastened to the lever and pen of the kymograph. As the bowl rotates, it forces the suspension past the pins of the head which tends to rotate the central axis against the resistance of the coil-spring. The amount of rotation thus imparted by the suspension to the shaft is recorded on the chart in arbitrary units ranging from 0 to 1000 against time rulings at 1-minute intervals. In performing a test, a small amount of flour (40 to 80 g.) is suspended in 400-450 ml. of distilled water in such a way that lumping is avoided and the suspension placed into the amylograph bowl. The machine is then started by means of a switch and the temperature allowed to increase automatically to 95° C., when it is held constant. The instrument is usually permitted to operate for a total elapsed time of 60 minues.

The amylograph permits the following determinations on flour-water suspensions (*125*).

1. Temperature at which gelatinization begins. Some correlation has been found to exist between the time at which gelatinization begins and

the crumb characteristics of the finished loaf, the latter being the poorer the longer the time elapsed before gelatinization is initiated. Apparently a far-reaching breakdown of the starch occurs by the alpha-amylase during the early oven stage and prior to the setting in of gelatinization.

2. Height of curve, or viscosity of suspension, on completion of gelatinization. Curve height is an important indication of the type of crumb

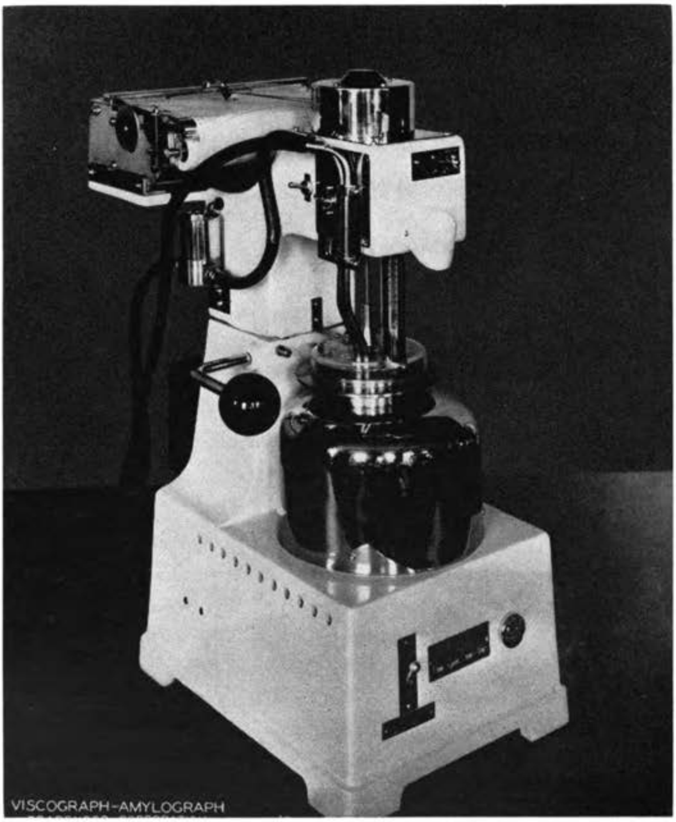


FIG. 103—The Brabender amylograph. (*Courtesy Brabender Corp.*)

that can be expected. Experience has shown that too high a curve, which corresponds to a high viscosity of the gelatinized flour suspension, points to a crumb in the finished loaf that will be dry and stale rapidly. Too low a curve, which results from excessive alpha-amylase activity, is normally indicative of a moist soggy crumb. The best type of crumb is obtained with a curve of medium height.

3. Susceptibility to enzyme additions. The alpha-amylase action of malt flour additions can be measured to a degree unattainable by other

methods. Increments of as small as 0.03 percent malt flour will produce recognizable changes in the amylogram curves.

The amylograph has also been applied with considerable success to the testing of the baking value of rye flours. Rye flour, lacking the gluten-forming proteins of wheat flour, depends for its baking quality to a much greater degree upon the gelatinization characteristics of its starch than is the case with wheat flour. The amount of water bound by the starch during gelatinization largely determines the type of crumb obtained in the baked rye loaf. This water binding capacity, in turn, is strongly influenced by the alpha-amylase activity during the early oven stage. An excessively high activity will dextrinize too great a portion of the starch, thereby reducing its water binding capacity. The result is a soggy, wet crumb. A rye flour of such excessive amylase activity will yield a very low curve in the amylograph. In the other extreme case, in which an insufficiency of amylase activity leaves the starch with too much water binding capacity so that a dry and easily staling crumb results in the baked loaf, the flour will produce a very high amylogram curve. Moderate enzyme activity required for superior crumb and texture is indicated by medium high curves for rye flour suspensions. The application of the amylograph to the testing of rye flours has been described by Brown and Harrel (*131*), while its use in the control of diastatic supplementation in baking has been more recently studied by Selman and Sumner (*132*).

THE MIXATRON

A major problem of the commercial baker since the introduction of power operated mixing equipment has been the determination of the correct absorption and mixing time of different types of flour. Numerous attempts have been made in the past to develop instruments capable of measuring dough consistency, or predicting the absorption and mixing requirements of various types and grades of flour. Two approaches were generally used to solve this problem. In the first, the mixing characteristics of a flour are determined in a small instrument using a small portion of flour; by analyzing the data obtained it is possible to predict with a fair degree of accuracy the proper absorption and mixing time to be used with a given flour. The farinograph is a good example of this type of instrumentation. Once a correlation factor has been established between this laboratory instrument and the commercial mixer, the baker is well able to set up the maximum commercial mixing conditions for new flours. A major shortcoming of the farinograph, however, is its inability to assist the baker in maintaining the uniformity of mixing conditions once the dough is being mixed in large volume pro-

duction. The second approach to the problem generally involved the use of current-meters and watt-meters which were attached to the motor driving the mixer, the idea being that current or power consumption was related to work done in dough mixing and could therefore be used to interpret changes in the dough's viscosity. Extensive tests have shown, however, that neither the current consumed by the motor nor its power consumption is sufficiently related to dough consistency to yield sufficiently accurate data (*133*). The chief limitations of current or power measurements were found to be: 1. The current consumed by the motor during the mixing of the dough is affected by many factors other than the dough consistency; 2. the measurement of power on a commercial watt-meter is inadequate because the average power consumed by the motor can be shown to be nearly constant with variations in dough consistency. In 1947 there were developed new electronic circuits designed to overcome the limitations of the electrical method theretofore used. These new circuits have been incorporated into a new device, called the mixatron, which permits the electronic measurement of true dough consistency (*134*).

The Patterson mixatron consists essentially of a recording meter on which charts are drawn showing the relative consistency of sponges and doughs plotted against time. The chart moves continuously whenever the mixer is in operation and stops when it is not operating. Thus the information obtained from the chart provides not only an instantaneous record of the consistency variations in the dough, but also full information as to mixing time. The recording instrument is connected with the power supply box of the particular mixer with which the device is to be employed. A commercial installation of the mixatron is shown in Figure 104.

Claims made for the mixatron include the following:

1. It facilitates and simplifies setting up of the proper mixing time and absorption conditions on new flours. This can be accomplished without the need of running involved absorption and mixing time series.

2. Once the mixing conditions for optimum bread quality have been established, the baker needs only to continue mixing the doughs in accordance with the curve attained for the optimum dough conditions to have full control of uniformity.

3. Since visual control is provided for the uniformity of the dough, the usual absorption safety factor is not necessary and the maximum absorption properties of the flour can be utilized.

4. The instrument provides a means of constant supervision over the human and mechanical factors which affect the mixing operation; i.e., any variation in the curves can be attributed either to human error in

weighing ingredients or misjudging the mixing time, or to mechanical inaccuracies in the water meter or flour scales, or to inadequacies in the mixer jacket refrigeration equipment.

Figures 105–106 illustrate the type of information that can be obtained with the aid of this instrument. Figure 105 shows the effect of absorption variation on the mixatron curve. In this as well as the other two mixatron curve figures, the different related curves have

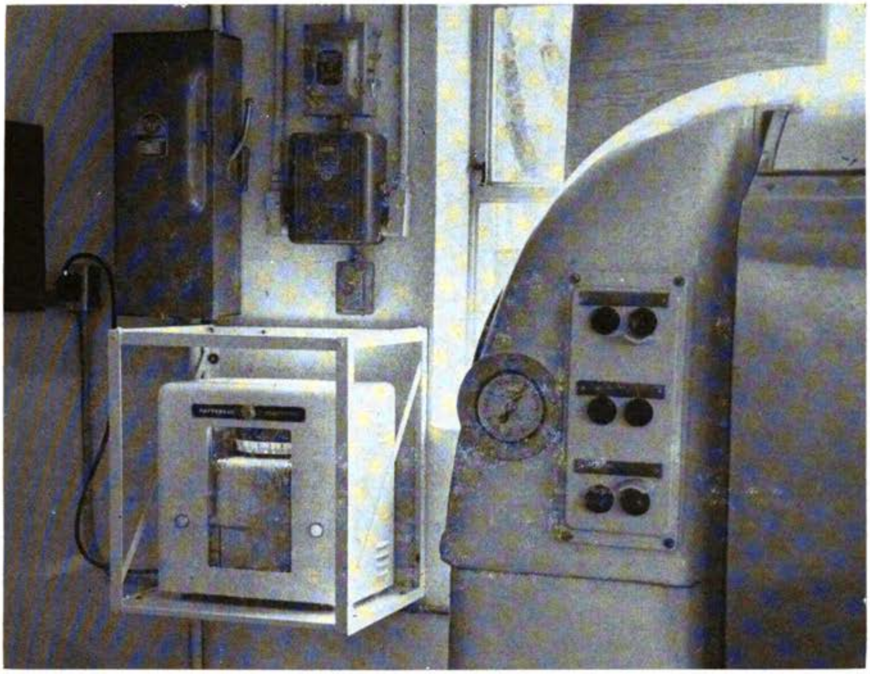


FIG. 104—A commercial mixatron installation. (*Courtesy C. J. Patterson Co.*)

been redrawn on one chart to conserve space and also to permit ready comparison of the curves. In actual mixatron operation, the individual curves are recorded singly. Generally, a variation of 1 percent in absorption will produce a clearly detectable difference in curves. A deficiency of water in the dough causes the curve to rise very rapidly during the initial stages of mixing. Given such a steep curve, it is possible to stop the mixer at an early stage and correct this water deficiency. On the other hand, as soon as the absorption becomes greater than optimum, the characteristic sag due to excessive hydration of the flour takes place immediately after the start of mixing. The effects of deliberate flour and water scaling errors are shown in Figure 106. The control curve is that of a Kansas flour in which 65 percent absorption is opti-

mum. When 15 percent flour was withheld, the curve assumed the form indicative of a very slack dough at the start of mixing. When the flour was replaced in four equal increments at the times indicated by the four arrows, the curve began to rise. Mixing was continued until the dough reached the peak value of the control, when it had received proper development. The third curve shows the effect of the initial withholding

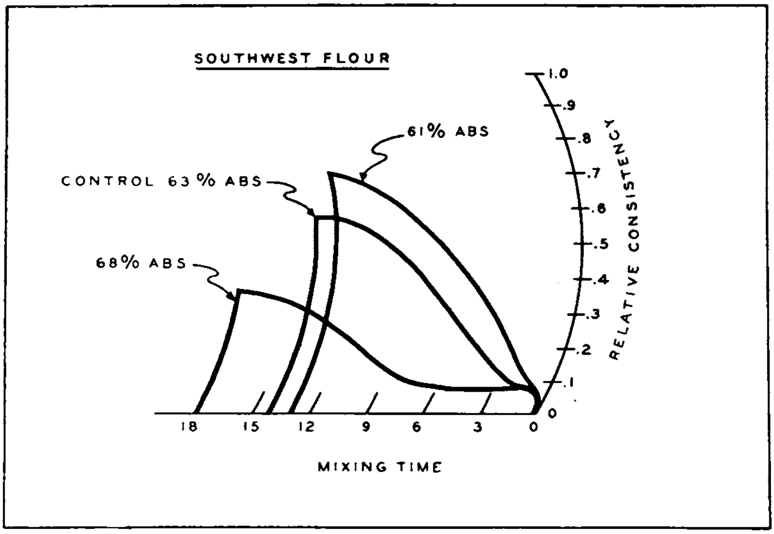


FIG. 105—Mixatron chart showing effect of absorption variation.

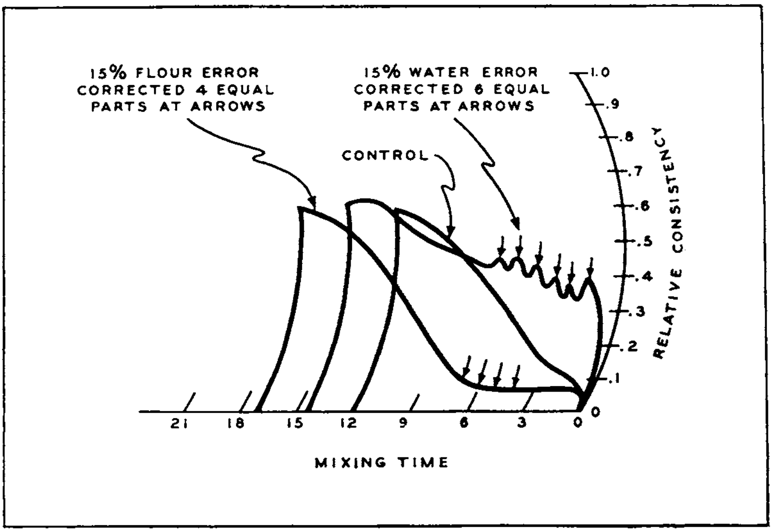


FIG. 106—Mixatron chart showing flour and water scaling errors.

of 15 percent water and its subsequent addition in six equal increments. Here the curve rose rapidly at first and then settled back to lower consistency as the balance of the water was added. Here again mixing is continued until the corrected curve reaches the peak shown by the control curve for optimum dough development. An analysis of these three curves thus reveals some practically very useful information. First of all, it is obvious that the curves, by their starting slope, show very clearly in each case the error due to water and flour deviations. Secondly, and possibly more important, the use of the mixatron provides a definite means of determining the proper mixing time when ingredients are added

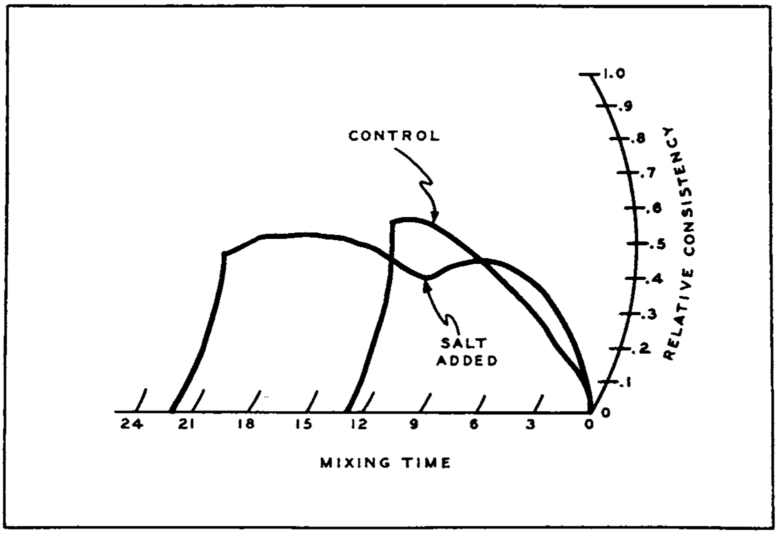


FIG. 107—Mixatron chart showing the effect of omitting salt until dough breakdown.

late in the mix. Figure 107 shows the effect of the omission of salt from a dough. In this case the curve rises rather sharply and is over the point of maximum consistency in a relatively short time. If salt is added at a later stage the curve resumes virtually a normal climb to peak consistency. Similarly, the effects of the accidental omission of such critical ingredients as dry milk solids, shortening, yeast food, etc., are clearly indicated by the dough consistency curves recorded by this instrument and can in most cases be corrected at an early stage of mixing.

METHODS OF TESTING AND ANALYSIS

The making of uniform bread and other baked products requires an adequate control over the raw materials used in their production. Of

primary importance in this connection is the testing of flour as the principal ingredient. Flours from different sources may vary considerably in their protein content and quality, ash, moisture, diastatic activity, color, etc., and it is essential that the changes in these characteristics from one flour to the next become known to the user prior to placing the flours into production. The function of individual flour tests is to disclose the specific property or character being tested for. Since the baker's interest extends to both the chemical and the physical characteristics of flour, appropriate chemical and physical tests are employed by the baking technologist and chemist.

The task of developing, evaluating and checking test procedures pertaining to flour and other ingredients used by the baking industry has been assumed in the United States largely by the Association of Official Agricultural Chemists and the American Association of Cereal Chemists. Both of these Associations publish their approved methods in volumes titled, respectively, "Official Methods of Analysis of the Association of Official Agricultural Chemists," whose seventh edition appeared in 1950, and "Cereal Laboratory Methods," which appeared in its fifth edition in 1947. An attempt will be made in this chapter to indicate the more pertinent tests relating to flour and dough evaluation as they appear in these volumes, as well as to describe briefly methods which are gaining increasing acceptance in cereal and baking laboratories although they have no "official" status.

Flour Sampling. It is obviously essential in carrying out any test or determination on a flour sample that the sample be as nearly representative of the entire shipment as possible if the test results are to possess validity. The sampling procedure most commonly used in the United States and prescribed by both the A.O.A.C. and the A.A.C.C. defines the number of samples to be taken from the shipment, the manner of withdrawing the samples and the manner of mixing the individual lots into a uniform average sample. The official directions for sampling are as follows (A.O.A.C.):

"Sample a number of sacks equivalent to the square root of the number in the lot, but not less than 10, i.e., 10 from 100 or less, 15 from 225, 20 from 400 sacks, etc.

"Select the sacks to be sampled according to their exposure in the ratio of 4 from the most exposed, 3 from the next less exposed, 2 from the next, and 1 from the least exposed portion of the lot.

"From each sack to be sampled, draw a core from one corner of the top diagonally to center of the sack by means of a cylindrical, pointed, polished metal trier, ½ inch in diameter, with a slit at least ⅓ of the circumference. Draw a second core from the other top corner to one half the distance to the center of the sack.

"Deliver the two cores at once to a clean, dry, air-tight container that has stood open for a few minutes near the lot of flour to be sampled, and seal immediately. Use a separate container for each sack sampled. One of the following containers may be used: (1) A pint fruit jar provided with a rubber gasket; (2) a rubber pouch that can be tied or sealed to exclude moisture or air; (3) a tin can or box with a moisture- and air-tight friction top.

"Before opening the sample for analysis, alternately invert and roll each container 25 times, or more if necessary, to secure a homogeneous mixture. Avoid extreme temperatures and humidities when opening the containers for analysis. Keep the sample tightly sealed at all other times."

MOISTURE DETERMINATION

The moisture content of flour represents the amount of water which is evaporated when the flour is dried under certain specified conditions. Since the amount of water driven off depends upon the duration of drying, the temperatures employed and the pressure in the drying chamber, these conditions must be accurately controlled to obtain valid and comparable results. It is quite impossible to determine the absolute moisture content of organic substances by any of the drying methods devised because the removal of the last traces of moisture entails such high temperatures as to cause the volatilization and loss of some of the organic matter. However, although the moisture content determined by heating is only relative, it is nevertheless sufficiently close to the actual moisture content to serve all practical requirements of accuracy. In addition to evaporative methods, certain instruments which are based on electrical conductivity and dielectric constants are used for moisture determination. Recently a method based on the use of wet and dry bulb thermometers in connection with agitation of the sample has been described by Dexter (*135*).

Moisture determinations are of importance to the baker for several reasons. First, if the moisture content of a flour shipment exceeds the specified limit, the excess moisture is paid for at the rate of the flour, which in other words means that the baker is buying water at a high price. Secondly, the stability of flour in storage is materially affected by its moisture content, being inversely related to the moisture content. Thirdly, if an undetected gain or loss in moisture of the flour takes place during storage, with the absorption used remaining constant, variations in dough characteristics are bound to occur.

There are three methods of moisture determination which have been standardized, namely the vacuum oven method, the air-oven method, and the aluminum plate method. They are all based on the evaporation

of the moisture in the sample and determining the difference in weight of the sample before and after drying, the difference representing the moisture content which is expressed as percent.

The vacuum method, designed to yield highly accurate results, utilizes a special oven in which a partial vacuum with a pressure equivalent to 25 mm. or less of mercury can be maintained by means of a vacuum pump. The oven is further equipped with a thermometer so positioned that the tip of its bulb is close to the moisture dishes. The vacuum in the oven is released by admitting dry air passing through a sulfuric acid gas-drying bottle which is connected to the oven. Additional equipment required include an air-tight desiccator containing reignited calcium oxide as the drying agent, a metal dish of about 55 mm. diameter and 15 mm. height, with an inverted slip-in cover that fits tightly on the inside, and a sensitive laboratory scale. The official instructions for carrying out the moisture determination by the vacuum-oven method are as follows (A.A.C.C. and A.O.A.C.):

"Weigh accurately about 2 g. of the well-mixed sample into a covered dish which previously has been dried at 98-100° C., cooled in the desiccator, and weighed soon after attaining room temperature. Loosen the cover (do not remove) and heat at 98-100° C. to constant weight (approximately 5 hours) in a partial vacuum having a pressure equivalent to 25 mm. or less of mercury. Admit dry air into the oven to bring to atmospheric pressure. Immediately tighten the cover on the dish, transfer to the desiccator, and weigh soon after room temperature is attained. Report the flour residue as total solids and the loss in weight as moisture (indirect method)."

The air-oven method, which yields results that approximate closely those obtained by the preceding method, is carried out at atmospheric pressure. Since it utilizes temperatures which are about 30° C. higher than those employed in the vacuum method the actual drying time is reduced to 1 hour as compared with 5 hours in the vacuum method. Except for the laboratory drying oven, which is of conventional design with provisions for maintaining the temperature at 130° C. (±3°) and for adequate ventilation, the remaining necessary equipment is the same as indicated for the vacuum method. The actual determination is carried out as follows (A.O.A.C.):

"In the cooled and weighed dish (provided with a cover) that has been previously heated to 130° C. (±3°), weigh accurately about 2 g. of the well-mixed sample. Uncover the sample, and dry the dish, cover, and contents for 1 hour in the oven provided with an opening for ventilation and maintained at 130° C. (±3°). (The 1-hour drying period begins when the oven temperature is actually 130° C.). Cover the dish while still

in the oven, transfer to the desiccator, and weigh soon after room temperature is attained. Report the flour residue as total solids and the loss in weight as moisture (indirect method)."

The *aluminum plate method* is the most rapid and simplest of the three procedures. Actual drying is carried out for only 15 minutes and cooling of the sample requires only 2 to 3 minutes so that a determination can be made in about 18 minutes. For this method the air oven is provided with an aluminum plate one-half inch or more thick which rests on the lowest shelf brackets. The oven is so regulated that the plate maintains a temperature of 140° C. (±1°). The temperature of the plate is determined by placing on it a small can containing fine sand and inserting the thermometer bulb to the bottom of the sand. An aluminum plate similar to that used in the oven may be used for cooling the dishes in place of a desiccator. The procedure prescribed for making the determination is as follows (A.A.C.C.):

"Weigh accurately approximately 2 g. of the well-mixed sample into a dish. Place dish and cover on the hot aluminum plate and dry for 15 minutes. Cover dish, transfer to the aluminum plate outside oven and cool for 2½ minutes (or until cold) and weigh. No desiccator is necessary if the sample is weighed within 5 minutes after becoming cold. Report the flour residue as total solids and the loss in weight as moisture (indirect method)."

ASH DETERMINATION

Ash is the mineral residue left when a small amount of flour is heated in a silica dish under prescribed conditions until all of the organic material is destroyed, but without causing the volatilization of non-combustible constituents. The most suitable temperature found for this purpose is within the range of 550° to 590° C. at which a dull red heat is produced. The heating is done in an electric muffle oven equipped with a pyrometer for indicating the temperature, and is continued until the sample is reduced to a gray-white ash. The residue is weighed and the weight converted to a percentage basis.

The ash represents most of the mineral elements obtained by the plant from the soil. As has been pointed out in Chapter VIII on Wheat Flour, the mineral constituents are not evenly distributed throughout the wheat berry, being far more concentrated in the bran than in the endosperm portions of the grain. Bran, on the whole, contains about 20 times as much ash as does the endosperm, the approximate values being 5 to 8 percent, and 0.28-0.38 percent, respectively. Hence the ash determination serves as a useful measure of the completeness of the separation obtained in milling. Because of the large difference in ash percentage

it is possible to estimate the grade of flour by means of the ash determination. Kline (*136*) has calculated from the ash content of soft wheat flour the percentage of shorts and bran present in the flour. Thus an ash content of 0.40 percent indicates a bran content of about 1.5 percent, while a flour with an ash content of 0.80 percent contains some 10 percent of bran and shorts. The ash content cannot, however, be used as a general index to flour quality (*136*).

Two official ashing methods are in general use. The first, or basic method, employs temperatures up to 590° C. and requires several hours, while in the second method, also called the magnesium acetate method, a temperature of 800° C. is used which reduces the ashing time to less than an hour. The apparatus required for both methods includes an electric muffle oven, and shallow, relatively broad ashing dishes of platinum, silica or nickel. For the second method, a standardized alcohol magnesium acetate solution is also used. The A.A.C.C. instructions for the basic method are as follows:

Basic Method: "Weigh 3-5 g. (±0.01 g.) of the well-mixed sample into an ashing dish which has been ignited, cooled in a desiccator and weighed soon after attaining room temperature. Place in the muffle furnace at not over 425° C. and gradually increase the temperature to 550° C. for soft wheat flours or 575° to 590° C. for hard wheat flours. Incinerate until a light gray ash is obtained or to constant weight. The ash must not be allowed to fuse. Cool in the desiccator and weigh soon after room temperature is attained. If desired, the ash may be transferred to a small counterpoise watch-glass and weighed directly. To transfer the ash, invert dish and usually the ash will be transferred completely to watch-glass by this procedure. If ash sticks, it may be removed by the point of a spatula."

The latest official A.O.A.C. method is identical to the above method except that it specifies 550° C. as the only ashing temperature, i.e., it does not provide for temperature adjustments to different flour types.

The Magnesium Acetate Method: The reagent employed is made, by the A.A.C.C. method, by dissolving 15 g. of $Mg(C_2H_3O_2)_2 \cdot 4H_2O$ in denatured alcohol and making up to 1 liter. The solution should be stored overnight and filtered if not clear. The official A.O.A.C. method specifies the dissolving of 4.054 g. of magnesium acetate in 50 ml. of water and making up to 1 liter with alcohol.

The instructions for the ashing determination by the A.A.C.C. method are as follows:

"Weigh 3 g. (±0.01 g.) flour into the ashing dish and add an accurately measured 3 ml. portion of the alcoholic magnesium acetate solution. The solution should be added in such a manner that it will spread evenly over the surface and wet all the flour.

"After 5 minutes, place the dish and contents in a muffle at 850° C. and allow to flame until carbonized. Close muffle door and allow dish and contents to remain until incineration is complete (30-45 minutes). Remove dish and cool in a desiccator.

"Tap the dish gently with a spatula to loosen the contents which are dumped directly on the balance pan and weighed. The weight of residue is corrected by subtracting the blank and percent of ash calculated.

"Blank determination: The blank correction may be determined by evaporating and igniting a 3 ml. portion of the magnesium acetate solution, but a more accurate blank is obtained by ashing the same flour by the basic method and by this method. The blank should be from 0.0085 to 0.0090 g."

The official A.O.A.C. magnesium acetate method reads as follows:

"From a burette add 5 ml. of the reagent to 3-5 g. of flour. Allow the mixture to stand 1-2 minutes, evaporate the excess alcohol, and place the sample in the muffle furnace maintained at 700° C., closing the door after flaming has ceased. When the incineration is complete, place the ashing dish in the desiccator until cool, then weigh. Run a blank determination on the solution and deduct the blank from the weight of the crude ash. Evaporate the blank cautiously."

TOTAL CRUDE PROTEIN

The protein content of flour is estimated by the so-called Kjeldahl method or one of its modifications. This method actually determines the amount of nitrogen contained in the flour and the figure so obtained is then multiplied by the factor 5.7 to yield the amount of protein. This factor is based on the assumption that the combined wheat proteins possess a nitrogen content of 17.5 percent. Although Jones (*138*) has criticized the factor of 5.7 since it is based only on the two principal proteins in flour, namely gliadin and glutenin, whereas wheat contains minor amounts of proteins of different nitrogen contents, long usage has firmly established its general acceptance. The method discloses only the amount of protein present in the flour and not its quality.

The Kjeldahl method is carried out in two steps: first, the flour is digested with concentrated sulfuric acid and other reagents at elevated temperatures for the purpose of converting all nitrogen in the sample into ammonium sulfate; secondly, the ammonia thus formed is distilled off into a measured quantity of standard sulfuric acid.

The following apparatus and reagents are required for the determination:

Apparatus: Long-necked Kjeldahl flasks of 500 or 800 ml. capacity, used for both digestion and distillation; cylindrical distilling bulbs of about 100 mm. length and 45 mm. diameter, whose outlet tube should

be of the same diameter as the condenser tube; heating units for digestion, heated either by gas or electrically.

Reagents: (1) Standard sulfuric or hydrochloric acid;

(2) Standard sodium hydroxide solution;

(3) Methyl red indicator, made by grinding 0.4 g. of methyl red with 29.6 ml. 0.05 *N* NaOH solution in a glazed procelain mortar and, after transfer to a 100 ml. flask, made up to 100 ml. with 95 percent ethyl alcohol;

(4) Concentrated sulfuric acid, containing 93-96 percent H_2SO_4;

(5) Potassium sulfate, powdered and free from nitrates and ammonia;

(6) Metallic mercury or mercuric oxide;

(7) Saturated sodium hydroxide solution;

(8) Sodium sulfide or sodium thiosulfate; these substances act as mercury precipitants and are added to the sodium hydroxide solution at the rate of 40 g. per liter for the Na_2S, or 80 g. per liter for the $Na_2S_2O_3$;

(9) Paraffin or engine oil to prevent foaming;

(10) Granular or mossy zinc or pumice to prevent bumping.

The A.A.C.C. procedure for carrying out the determination is as follows:

"Weigh accurately 1 g. of the well-mixed sample into a Kjeldahl flask and add approximately 10 g. potassium sulfate (or sulfate mixture), and 0.5 g. mercuric oxide or equivalent in metallic mercury. Introduce 25 ml. concentrated sulfuric acid and thoroughly mix acid, salts and sample. Digest until at least 20 minutes after the contents become colorless. (Depending upon capacity of heating units, digestion time will range from 40 to 60 minutes.)

"Cool, dilute with 200-300 ml. water, and add a small amount of zinc or pumice. In case of excessive frothing add 1 ml. of engine oil or a piece of paraffin the size of a pea. Next add sufficient sodium hydroxide solution containing Na_2S, K_2S or $Na_2S_2O_3$ to make the solution alkaline and to precipitate the mercury. Pour the alkali down the side of the flask so that it does not immediately mix with the acid solution.

"Connect the flask to the condenser, mix the contents by shaking, and distill until all the ammonia has passed over into a measured quantity of standard acid. The first 150 ml. will usually contain all the ammonia. Titrate with standard alkali using red as indicator. Calculate the percent nitrogen and convert to percent crude protein by multiplying by the factor 5.7."

CRUDE GLUTEN

Although the terms protein and gluten are frequently used as synonyms—they are in fact closely associated—they do not designate the

same thing. Protein comprises all the nitrogenous material in the flour and is determined by the Kjeldahl method described above. Gluten, on the other hand, constitutes the residue obtained by working and washing a small piece of dough in water. This invariably involves the loss of certain water-soluble protein substances. However, as Swanson (*139*) has pointed out, small amounts of non-protein material, such as very fine starch granules, fiber, fat and ash, defy complete removal and remain with the gluten. The amount of protein material lost in washing is nearly balanced by the non-protein material retained so that the figures obtained for dry gluten are very nearly the same as the figures for percent of total protein. Thus Swanson (*139*) cites the following relationships between percentages of protein, dry and wet gluten:

TABLE 114. RELATIONSHIP BETWEEN TOTAL PROTEIN OF FLOUR, DRY AND WET GLUTEN

Flour	No. of Samples	Protein %	Dry Gluten	Wet Gluten
Short Patent............	9	11.87	11.68	36.3
Long Patent.............	11	12.56	12.50	39.5
Straight.................	15	12.52	12.31	38.2

It will be seen that the values for protein and dry gluten are quite close. There also appears to exist a more or less definite relationship between wet and dry gluten, with the figures for the wet gluten being a little over three times those of dry gluten. The ratio of wet gluten to dry gluten has occasionally been used as an index to quality on the supposition that the greater the water hold capacity of the gluten, the better its quality.

The gluten test no longer possesses the importance it formerly had since accurate crude protein determinations are carried out routinely in mill and baking laboratories. Also, there are now available a number of mechanical dough tests which are designed to provide similar qualitative information. The principal advantages of the test are that it requires a minimum of equipment and that, in the hands of a skilled operator, it yields useful information as to the general quality of the gluten as revealed by its feel, color, and behavior while being worked.

The procedure prescribed by the A.A.C.C. for washing out the gluten is as follows:

"Weigh 25 g. of flour into a porcelain cup or mortar, add sufficient tap water (about 15 ml.) to form a firm dough ball, and work into a dough with a spatula or pestle, taking care that none of the material adheres to the utensil. After allowing the dough to stand in water at

room temperature for 1 hour, knead gently in a stream of tap water over bolting cloth (approx. 60 GG) until the starch and all soluble matter are removed. This operation requires approximately 12 minutes.

"To determine whether or not the gluten is approximately starch-free, let 1 or 2 drops of the wash water, obtained by squeezing, fall into a beaker containing perfectly clear water. If starch is present a cloudiness appears.

"Allow the gluten thus obtained by washing to stand in water for an hour, press as dry as possible between the hands, roll into a ball, place in a weighed flat-bottomed dish and weigh as moist gluten. Transfer to an oven, dry to constant weight at 100° (24 hours), cool, and weigh as dry gluten."

STARCH DETERMINATION

The starch content of a flour may be arrived at by a number of methods which vary considerably in their accuracy and complexity. Thus, starch may be determined by difference, i.e., by determining the other flour constituents such as moisture, ash, protein, fat, and crude fiber. Or the starch may be removed by a washing-out process similar to that employed in the gluten washing test, then dried and weighed. The generally used procedure is to hydrolyze the starch into sugars with the aid of acid or diastase and then determine the sugar produced by an appropriate method. Polarimetric methods are also used in which the starch is dissolved in a hot calcium chloride solution under standardized conditions, the soluble protein removed by stannic chloride and the solution then polarized.

The official A.O.A.C. method of direct acid hydrolysis, which includes as starch the pentosans and other carbohydrate substances that undergo hydrolysis and are converted into reducing sugars on boiling with hydrochloric acid, is carried out as follows:

"Stir the weighed sample, representing 2.5-3 g. of the dry material, in a beaker with 50 ml. of cold water for 1 hour. Transfer to a filter and wash with 250 ml. of cold water. Heat the insoluble residue for 2.5 hours with 200 ml. of water and 20 ml. of HCl (specific gravity 1.125) in a flask provided with a reflux condenser. Cool, and nearly neutralize with NaOH. Complete the volume to 250 ml., filter, and determine the dextrose in an aliquot of the filtrate. The weight of the dextrose obtained multiplied by 0.90 gives the weight of the starch."

Detailed directions for carrying out starch determinations by the rather involved Rask method, the diastase method with subsequent acid hydrolysis, and the polarimetric method are published in the A.A.C.C. volume on "Cereal Laboratory Methods" which should be consulted.

SUGAR DETERMINATION

It is at times important to determine the sugar content of flour since an abnormally high sugar content is generally indicative of partial germination of the wheat with its attendant increase in diastatic activity. The sugars occurring in flour are of both the reducing type, such as dextrose, maltose, and lactose, and the non-reducing type, of which sucrose is the best known example. Reducing sugars differ from non-reducing sugars in their ability to reduce such oxidizing reagents as Fehling's solution and ferricyanide. Non-reducing sugars lack this ability but, on treatment with acid, are "inverted" to simple sugars possessing reducing properties. The Munson and Walker method, using Fehling's solution (obtained by combining a copper sulfate solution with an alkaline solution of sodium potassium tartrate or Rochelle salts) is generally used in this country for determining sugar in solutions. In practice, an extract containing the sugar is treated under standardized conditions of time and temperature with an excess of Fehling's solution. Cuprous oxide is precipitated as a result of the reduction that takes place and is then filtered off, dried and weighed. The amount of sugar is obtained by reference to an empirical table which lists weights of cuprous oxide versus weights of pure dextrose, invert sugar, lactose and maltose.

For the determination of both reducing and non-reducing sugars in flour, the method adopted as official by both the A.O.A.C. and A.A.C.C. specifies ferricyanide as the oxidizing agent. The various reagents, as well as the procedures for their preparations and for the carrying out of the determinations itself, are as follows:

Reagents: (1) Ethyl alcohol, 95 percent by volume.

(2) Acid buffer solution. Dissolve 3 ml. glacial acetic acid, 4.1 g. anhydrous sodium acetate, and 4.5 ml. H_2SO_4 (specific gravity 1.84) and dilute to 1 liter with water.

(3) Sodium tungstate, 12 percent. Dissolve 12.0 g. $Na_2WO_4 \cdot 2H_2O$ and dilute to 100 ml.

(4) Alkaline ferricyanide solution, 0.1 *N*. Dissolve 33 g. pure dry $K_2Fe(CN)_6$ and 44 g. anhydrous Na_2CO_3 and dilute to 1 liter. To standardize, add to 10 ml. of this solution 25 ml. acetic acid-salt solution, 1 ml. soluble starch-KI solution and titrate with 0.1 *N* thiosulfate. Exactly 10 ml. should be required to discharge the blue color completely.

(5) Acetic acid-salt solution. Dissolve completely 70 g. KCl and 40 g. $ZnSO_4 \cdot 7H_2O$ in 750 ml. H_2O, add slowly 200 ml. glacial acetic acid and dilute to 1 liter with water.

(6) Soluble starch-potassium iodide solution. Suspend 2 g. soluble starch in a small quantity of cold water and pour slowly into boiling water with constant stirring. Cool thoroughly (or the resulting mixture

will be dark colored), add 50 g. KI, dilute to 100 ml. and add one drop of saturated NaOH solution.

(7) Thiosulfate solution, 0.1 *N*. Dissolve 24.82 g. $Na_2S_2O_3 \cdot 5H_2O$ and 3.8 g. borax and make up to 1 liter.

NOTE: The following "blank" determination should be made with each day's series of sugar determinations to guard against changes in the ferricyanide reagent and to correct for any reducing impurities in the reagents: Combine 5 ml. alcohol (1), 50 ml. acid buffer (2), and 2 ml. sodium tungstate (3). To 5 ml. of this mixture (used in place of 5 ml. flour extract) add 10 ml. of the ferricyanide solution (4) and proceed as in the determination of reducing sugars below. It should require 10 ml. of the thiosulfate to discharge the blue starch-iodine color. If the titration ("thiosulfate equivalent") falls within 10 (±.05) ml. the reagents need not be discarded but the appropriate correction should be made in the maltose calculation.

Preparation of extract: Introduce 5.675 g. flour into a 100 or 125 ml. Erlenmeyer flask. Tip the flask so that all the flour is at one side and wet the flour with 5 ml. alcohol. Then tip the flask so that the wet flour is at the upper side and add 50 ml. of the acid buffer solution, keeping the solution from coming in contact with the flour until it has all been added to the flask. Then shake the flask to bring the flour into suspension. Add immediately 2 ml. of the sodium tungstate solution and again mix thoroughly. Filter at once (Whatman No. 4 or equivalent), discarding the first 8-10 drops of filtrate.

Reducing sugars: Pipette 5 ml. extract into a test tube of approximately 50 ml. capacity. Add with a pipette exactly 10 ml. alkaline ferricyanide reagent, mix and immerse the test tube in a vigorously boiling water bath. The surface of the liquid in the test tube should be 3-4 cm. below the surface of the boiling water. (The delay between the filtering of the extract and the treatment in the boiling water bath should not exceed 15-20 minutes. Further delay may cause error due to sucrose hydrolysis in the acid solution.) Allow the test tube to remain in the boiling water bath exactly 20 minutes. Cool the test tube and contents under running water and pour at once into a 100 or 125 ml. Erlenmeyer flask. Rinse out the test tube with 25 ml. acetic acid-salt solution, adding rinsings to solution in Erlenmeyer flask. Mix, add 1 ml. of soluble starch-KI solution, mix thoroughly and titrate with 0.1 *N* thiosulfate to the complete disappearance of the blue color. (A 10 ml. micro-burette is recommended for this titration). Calculate ml. ferricyanide reduced by subtracting ml. thiosulfate required from the thiosulfate equivalent of the ferricyanide reagent (*cf.* "blank" above). Compute reducing sugars as mg. maltose per 10 g. flour by reference to Table 115.

TABLE 115. FERRICYANIDE-MALTOSE-SUCROSE CONVERSION TABLE*

0.1 *N* Ferricyanide reduced	Maltose per 10 g. flour	Sucrose per 10 g. flour	0.1 *N* Ferricyanide reduced	Maltose per 10 g. flour	Sucrose per 10 g. flour
ml.	mg.	mg.	ml.	mg.	mg.
0.10	5	5	4.50	237	214
0.20	10	10	4.60	244	218
0.30	15	15	4.70	251	223
0.40	20	19	4.80	257	228
0.50	25	24	4.90	264	233
0.60	31	29	5.00	270	238
0.70	36	34	5.10	276	242
0.80	41	38	5.20	282	247
0.90	46	43	5.30	288	251
1.00	51	48	5.40	295	256
1.10	56	52	5.50	302	261
1.20	60	57	5.60	308	266
1.30	65	62	5.70	315	270
1.40	71	67	5.80	322	275
1.50	76	71	5.90	328	280
1.60	80	76	6.00	334	285
1.70	86	81	6.10	341	290
1.80	90	86	6.20	347	294
1.90	96	91	6.30	353	299
2.00	101	95	6.40	360	304
2.10	106	100	6.50	367	309
2.20	111	104	6.60	373	313
2.30	116	109	6.70	379	318
2.40	121	114	6.80	385	323
2.50	126	119	6.90	392	328
2.60	130	123	7.00	398	333
2.70	135	128	7.10	406	337
2.80	140	133	7.20	412	342
2.90	145	138	7.30	418	347
3.00	151	143	7.40	425	352
3.10	156	148	7.50	431	357
3.20	161	152	7.60	438	362
3.30	166	157	7.70	445	367
3.40	171	161	7.80	451	372
3.50	176	166	7.90	458	377
3.60	182	171	8.00	465	382
3.70	188	176	8.10	472	387
3.80	195	181	8.20	478	392
3.90	201	185	8.30	485	497
4.00	207	190	8.40	492	402
4.10	213	195	8.50	499	407
4.20	218	200	8.60	505	...
4.30	225	204	8.70	512	...
4.40	231	209	8.80	519	...

* Methods of Analysis of the A.O.A.C. 7th Edition (1950). Association of Official Agricultural Chemists, Washington, D. C.

Non-reducing sugars: Pipette 5 ml. of the filtered clarified flour extract into a test tube of approximately 50 ml. capacity and immerse in a vigorously boiling water batch for 15 minutes. Cool test tube and contents under running water, add exactly 10 ml. of the alkaline ferricyanide reagent and carry out the reduction and subsequent titration as described above for reducing sugars. Again calculate ml. ferricyanide reduced, subtract from this value the ml. ferricyanide reduced in determination for reducing sugars above and express the difference as mg. sucrose per 10 g. flour by reference to Table 115.

DIASTATIC ACTIVITY DETERMINATION

The importance of the amylases in dough fermentation has been discussed in some detail in Chapter V where a number of methods commonly used for the determination of diastatic activity are also briefly indicated. At this point, only the procedure adopted as official by the A.A.C.C. and the A.O.A.C. is reproduced.

Reagents: (1) Buffer solution. Make up 3 ml. of acetic acid and 4.1 g. of anhydrous sodium acetate to 1 liter with H_2O; the pH of this solution is 4.6-4.8.

(2) Alkaline ferricyanide solution, 0.05 *N*. Dissolve 16.5 g. of pure dry $K_3Fe(CN)_6$ and 22 g. of anhydrous Na_2CO_3 in water and make to 1 liter. Solution maintains its strength for a long period if kept in a dark glass bottle away from the light.

(3) Sodium thiosulfate solution, 0.05 *N*. Dissolve 12.41 g. of clear crystals of $Na_2S_2O_3 \cdot 5H_2O$ in water and dilute to 1 liter. If carbon dioxide-free redistilled water is used in making up this solution, it will retain its normality for a long time, whereas with ordinary water it is likely to deteriorate slowly on standing. Check the sodium thiosulfate solution against the ferricyanide solution as follows: To 10 ml. of the $K_3Fe(CN)_6$ solution add 25 ml. of the acetic acid reagent, 1 ml. of the 50 percent KI solution, and 2 ml. of the soluble starch indicator. Titrate with the $Na_2S_2O_3$ solution. It should require exactly 10 ml. of the $Na_2S_2O_3$ solution to completely discharge the blue starch-iodine color. Standardize the $Na_2S_2O_3$ solution against pure iodine if necessary.

(4) Acetic acid reagent. Dissolve 200 ml. acetic acid, 70 g. KCl, and 20 g. of $ZnSO_4 \cdot 7H_2O$ and dilute to 1 liter with water.

(5) Potassium iodide solution; 50 percent. Dissolve 50 g. of KI in water, add 1 drop of NaOH solution (1 + 1), and make to 100 ml. with water.

(6) Soluble starch indicator. 1 percent of soluble starch in 30 percent NaCl solution. Prepare soluble starch suspension and pour slowly into boiling water. Add the NaCl and make to volume. Solution should be transparent and colorless.

Determination: Introduce 5 g. of flour and a teaspoonful of ignited quartz sand into a 100 or 125 ml. Erlenmeyer flask, and mix by rotating the flask. Add 46 ml. of the buffer solution, and again mix by rotating the flask until all the flour is in suspension. (Flask and all the ingredients should be individually brought to 30° C. before the ingredients are mixed together.) Digest for 1 hour at 30° C., preferably in an accurately controlled water thermostat, shaking the flask (by rotation) every 15 minutes. At the end of the hour add 2 ml. 3.58 N H_2SO_4 and mix thoroughly. Add 2 ml. of 12 percent sodium tungstate solution, mix, let stand 1-2 minutes. Filter through paper (No. 4 Whatman or equivalent), discarding the first 8 to 10 drops.

Pipette 5 ml. of filtered extract into a test tube of about 50 ml. capacity (18-20 mm. diameter). Pipette exactly 10 ml. of the $K_3Fe(CN)_6$ solution into the 5 ml. of extract in the test tube, and immerse the test tube in vigorously boiling water bath. Have the surface of the liquid in the test tube 3-4 cm. below the surface of the boiling water. (Delay between the filtering of the extract and treatment in boiling water bath should not be more than 15-20 minutes; further delay may cause slight error due to sucrose hydrolysis in the acid solution). Allow the test tube to remain in the boiling water bath *exactly* 20 minutes. Cool the test tube and its contents under running water, and pour at once into a 100 or 125 ml. Erlenmeyer flask. Rinse out the test tube with 25 ml. of the acetic acid solution, and add to the contents of the Erlenmeyer flask, with thorough mixing. Add 1 ml. of the KI solution, followed by 2 ml. of the starch indicator, and mix thoroughly. Titrate with the 0.05 N $Na_2S_2O_3$ solution to complete disappearance of the blue color. Subtract the number of ml. of 0.05 N $Na_2S_2O_3$ solution used in titration from 10, which gives the ml. of 0.05 N $K_3Fe(CN)_6$ solution reduced to ferrocyanide by the reducing sugars in the flour extract. This value represents a definite quantity of maltose, which may be ascertained by consulting Table 116. When 5 ml. of flour extract is used, as herein specified, it is necessary merely to multiply mg. of maltose by 20 to obtain mg. of maltose in 10 g. of flour in 1 hour's diastasis. This is the value that is recorded and reported as a measure of the diastatic value of the flour in question.

The foregoing specifications may be used with all ordinary flours whose values for mg. of maltose produced by 10 g. of flour in 1 hour will seldom, if ever, exceed 350. For materials giving higher values, such as products from malted or sprouted grain, use smaller portions of the extract, i.e., 1, 2 or 3 ml. instead of 5 ml. In such cases, however, add enough water to make up difference, and use different factor for converting results into mg. of maltose per 10 g. of flour. Thus, when 2 ml. of extract is used, multiply the value obtained from the table by 50 instead

of 20. If the material in the test tube is colorless instead of yellow after treatment in the boiling water bath and gives no blue color upon addition of KI, it is apparent that there was more than enough maltose to reduce all the ferricyanide, and the determination must be repeated with a smaller quantity of the extract.

Blank Determination: A blank determination, designed to indicate the quantity of reducing sugar originally present in the flour—the value for which presumably should be deducted from the total maltose value after 1 hour's diastasis—has been generally regarded as an essential step in the estimation of flour diastatic activity. This operation, however, is ordinarily unnecessary when dealing with flour milled from sound wheat, because the quantity of reducing sugars originally present in such flour is so small and so nearly constant that it may be disregarded for all

TABLE 116. MALTOSE CONVERSION TABLE*

0.05 *N* Ferri-cyanide reduced	Maltose equiv-alent	0.05 *N* Ferri-cyanide reduced	Maltose equiv-alent	0.05 *N* Ferri-cyanide reduced	Maltose equiv-alent	0.05 *N* Ferri-cyanide reduced	Maltose equiv-alent
ml.	mg.	ml.	mg.	ml.	mg.	ml.	mg.
0.1	0.2	2.6	4.2	5.1	8.3	7.6	12.3
0.2	0.3	2.7	4.4	5.2	8.4	7.7	12.5
0.3	0.5	2.8	4.5	5.3	8.6	7.8	12.7
0.4	0.6	2.9	4.7	5.4	8.7	7.9	12.9
0.5	0.8	3.0	4.9	5.5	8.9	8.0	13.0
0.6	1.0	3.1	5.0	5.6	9.1	8.1	13.2
0.7	1.1	3.2	5.2	5.7	9.2	8.2	13.4
0.8	1.3	3.3	5.3	5.8	9.4	8.3	13.5
0.9	1.5	3.4	5.5	5.9	9.6	8.4	13.7
1.0	1.6	3.5	5.7	6.0	9.7	8.5	13.9
1.1	1.8	3.6	5.8	6.1	9.9	8.6	14.0
1.2	1.9	3.7	6.0	6.2	10.0	8.7	14.2
1.3	2.1	3.8	6.2	6.3	10.2	8.8	14.4
1.4	2.3	3.9	6.3	6.4	10.4	8.9	14.6
1.5	2.4	4.0	6.5	6.5	10.5	9.0	14.8
1.6	2.6	4.1	6.6	6.6	10.7	9.1	15.0
1.7	2.8	4.2	6.8	6.7	10.9	9.2	15.2
1.8	2.9	4.3	7.0	6.8	11.0	9.3	15.4
1.9	3.1	4.4	7.1	6.9	11.2	9.4	15.6
2.0	3.2	4.5	7.3	7.0	11.3	9.5	15.9
2.1	3.4	4.6	7.5	7.1	11.5	9.6	16.1
2.2	3.6	4.7	7.6	7.2	11.7	9.7	16.5
2.3	3.7	4.8	7.8	7.3	11.8	9.8	17.0
2.4	3.9	4.9	7.9	7.4	12.0	9.9	—
2.5	4.1	5.0	8.1	7.5	12.2	10.0	—

* Official Methods of Analysis of the A.O.A.C. 7th edition (1950). Association of Official Agricultural Chemists, Washington, D. C.

practical purposes. The blank determination may therefore conveniently be omitted in ordinary routine testing. It need be used only when there is occasion to doubt soundness of the wheat. To make the blank determination, proceed as follows: Add to 5 g. of the flour and a teaspoonful of quartz sand in a 100 or 125 ml. Erlenmeyer flask 48 ml. of H_2SO_4 (4 + 996), preferably pre-cooled to 0° C. Shake the mixture thoroughly, allow to stand 2 minutes, and filter through No. 4 Whatman (or equivalent) paper. Using 5 ml. of the clear filtrate, proceed as directed for the regular maltose determination.

GAS PRODUCTION MEASUREMENT

The characteristic structure and volume of yeast-fermented products are based upon the evolution of carbon dioxide gas by the yeast. A desirable loaf volume is obtained only if the dough provides the yeast with a suitable environment for growth to ensure adequate gas production and at the same time possesses a gluten which is capable of retaining a good proportion of the gas so produced. Gas retention is most conveniently determined by measuring the volume increase of a fermenting dough, while gas production may be determined by any of a large number of gas testing instruments.

The A.A.C.C. book on Cereal Laboratory Methods describes a pressuremeter and a volumetric method for measuring the gassing power of doughs. The former employs the pressuremeter described by Sandstedt and Blish (*140*) and Malloch (*141*). The pressure generated in the vessel is measured by means of a mercury manometer in the Sandstedt and Blish apparatus and by pressure gauges in the Malloch apparatus. In the volumetric method use is made of the fermentation vessel first described by Bailey and Johnson (*142*) and later improved by Bailey (*143*). In each case a water bath, which can be maintained at a constant temperature of 30° C., provides the necessary temperature control.

In the pressuremeter method, 10 g. of flour (on the 14 percent moisture basis) and 7 ml. of water containing 0.3 g. yeast in suspension are placed in the pressure jar, which previously has been warmed to 30° C., and mixed with a spatula. The manometer is then screwed on tightly and the apparatus is placed in the water bath. After a lapse of 5 minutes to allow the entire system to come to temperature, the manometer is adjusted to zero by opening the valve for an instant, and the time is noted. All the later readings are taken with reference to the initial time. After any selected time, the total distance in mm. from one end of the mercury column to the other is measured and recorded.

In the volumetric method the fermentation vessel is connected by means of a flexible rubber tubing to an inverse-calibrated burette which

is inverted in a 23 percent sodium chloride solution. Pint and half-pint fruit jars may also be made to serve as the fermentation vessels. If the copper fermentation vessels are used, the dough is made with 100 g. of flour, 3 g. of yeast and sufficient water to yield a dough of proper consistency. Mixing should preferably be done mechanically by means of a small laboratory mixer. The time at completion of mixing is recorded as zero fermentation time. An amount of dough equivalent to 40 g. of flour is then scaled off, placed in the fermentation vessel, and the fermentation and gas measuring system closed securely. Gas production is recorded at desirable intervals. The pressure inside and outside the burette should be equalized when readings are taken or when the burette is reset after its capacity has been reached. If fruit jars are used as the fermentation vessels, the amount of dough is reduced to the equivalent of 25 g. of flour in the case of the pint jar, whereas with the half-pint jar 14 g. of flour and 10 ml. of yeast suspension containing 0.42 g. of yeast are mixed directly in the jar with a small spatula.

Mention may also be made at this point of what appears to be a simple but accurate apparatus for measuring gas production. Known as the British Arcady apparatus, it is described by Kent-Jones and Amos (*19*) as consisting of a thermostatically controlled water-bath in which are two screw-top jars, one with an approximate capacity of 900 ml. and the other of 1,350 ml. The larger jar is filled nearly to the top with paraffin oil and the other jar accommodates the fermenting dough. The jars are interconnected by a brass tubing which passes through leak-proof brass plates in the top of the jars. The larger jar is equipped with an additional tubing which extends close to the bottom of the jar at one end while the other end feeds into a graduated cylinder. The gas evolved forces the oil out of the larger jar into the measuring cylinder where its volume may be read at convenient intervals. By following a prescribed procedure of dough preparation excellent duplicates are said to be attainable with this apparatus.

ACIDITY AND pH DETERMINATIONS

The concepts of titratable acidity and active acidity or pH have been discussed at some length in Chapter IV. At this point only the procedures employed in determining titratable acidity and the pH will be indicated.

Acidity Determination. The following method for carrying out a titration is suggested by Kent-Jones and Amos (*19*):

Prepare a thin flour paste, using 5 g. of flour and freshly distilled, carbon dioxide-free water. Dilute the paste into a suspension with additional water

until approximately 40-50 ml. is used. Add several drops of phenolphthalein indicator (0.5 percent alcoholic solution) and titrate with 0.05 *N* NaOH solution or KOH solution until a faint pink color appears which does not fade on stirring for 30 seconds. The acidity is calculated as monopotassium phosphate (KH_2PO_4), 1 ml. of 0.05 *N* alkali being equivalent to 0.0068 g. of KH_2PO_4.

The original A.A.C.C. method called for 18 g. of flour being extracted with 200 ml. of distilled, carbon dioxide-free water, holding the extract for one hour at 40° C., and carrying out the titration on the filtrate using phenolphthalein as the indicator.

pH Determination. Two general procedures are employed for determining the hydrogen ion concentration, namely, the colorimetric method in which indicators that undergo color changes at certain pH values are used, and the electrometric method in which the electric potential is measured by a special instrument.

Electrometric Method: The apparatus required for this determination consists of electrodes and a potentiometer that have been standardized by buffer solutions of known hydrogen ion activity. Standardization is preferably carried out with a buffer solution of pH 4.01 (0.05 *M* solution of acid potassium phthalate) and of pH 9.18 (0.01 *M* $Na_2B_4O_7 \cdot 10H_2O$), both at 25° C.

The actual determination by the A.A.C.C. procedure is carried out as follows: Ten g. of flour or a multiple thereof is placed in a dry Erlenmeyer flask and 100 ml. of freshly boiled distilled water at a temperature of 25° C. added. The flask is agitated until an even suspension free from lumps is obtained. The suspension is allowed to stand for 30 minutes at 25° C. with either continuous or intermittent stirring to keep the flour particles in suspension. The flour particles are then permitted to settle for 10 minutes, the supernatant liquid decanted into the electrode vessel and the pH determined immediately using a potentiometer and electrodes which have been calibrated as indicated above.

Colorimetric Method: This method is based upon a comparison of a sample of clear flour extract to which an indicator has been added with standardized indicator solutions of known pH values. The comparison is carried out in a suitable comparator which may either be purchased or constructed by drilling six deep holes in pairs and parallel in a block of wood, each hole being large enough to hold one ¾″ test tube or ampoule, and then drilling smaller holes perpendicular to and running through each pair of the larger holes for viewing the test tubes placed in the larger holes.

The necessary buffer solutions are prepared as follows:

(a) Stock Solutions: (1) *Potassium acid phthalate, 0.2 M.* Dissolve 40.836 g. of previously dried salt and make up to 1 liter.

(2) *Monopotassium phosphate solution, 0.2 M.* Dry the salt to constant weight, dissolve 27.232 g. and make up to 1 liter.

(3) *Boric acid-potassium chloride solution, 0.2 M.* 12.405 g. of H_3BO_3 dried to constant weight and 14.912 g. of dried KCl are dissolved and diluted to 1 liter.

(4) *Sodium hydroxide solution, 0.2 M.* This solution may be closely standardized and should be as free as possible from carbonate.

(b) Buffer Solutions: These are prepared from the above stock solutions. In each case, dilution should be made to 200 ml.

Phthalate-NaOH Mixtures

pH	*0.2 M* KH Phthalate (ml)	*0.2 M* NaOH (ml)
5.0	50	23.65
5.2	50	29.75
5.4	50	35.25
5.6	50	39.10
5.8	50	43.10
6.0	50	45.40
6.2	50	47.00

KH_2PO_4-NaOH Mixtures

pH	*0.2 M* KH_2PO_4 (ml)	*0.2 M* NaOH (ml)
5.8	50	3.66
6.0	50	5.64
6.2	50	8.55
6.4	50	12.60
6.6	50	17.74
6.8	50	23.60
7.0	50	29.54
7.2	50	34.90
7.4	50	39.34
7.6	50	42.74
7.8	50	45.17
8.0	50	46.85

H_3BO_3-KCl-NaOH Mixtures

pH	*0.2 M* H_3BO_3, KCl (ml)	*0.2 M* NaOH (ml)
7.8	50	2.65
8.0	50	4.00
8.2	50	5.90
8.4	50	8.55
8.6	50	12.00

(c) Colorimetric Standards: These are prepared by placing 20 ml. of the buffered solution in test tubes ¾″ in diameter, and adding 0.5 of indicator solution. Unless they are sealed, the test tubes should not be

kept longer than a few days because the buffer solution may spoil. The following indicators, which cover the pH range from 3.8 to 8.4, are recommended by the A.O.A.C. for use in cereal work:

	A	pH
Bromocresol green	14.3	3.8-5.4
Chlorophenol red	23.6	4.8-6.4
Bromothymol blue	16.0	6.0-7.5
Phenol red	28.2	6.8-8.4

A = ml. of 0.01 *N* NaOH per 0.1 g. of indicator to form the monosodium salt. Dilute to 250 ml. for 0.04 percent reagent.

Determination (*A.A.C.C. procedure*): To 10 g. of sample, add 100 ml. cool, recently boiled distilled water and digest at 25° C. for 30 minutes. Shake occasionally during digestion period. Allow suspension to stand quietly for 15 minutes and then decant supernatant liquid through a folded, hardened, dry filter paper. Discard first 5 ml. and then catch the next 60 ml. (20 ml. in each of three ¾″ test tubes). Add 0.5 of the proper indicator to one tube. Place this tube in one of the center pair of holes of the comparator block. Behind this put a test tube of exactly the same size containing an equal quantity of water. At each side place a tube containing 20 ml. of a buffer solution plus 0.5 ml. of the same indicator. Behind each buffer solution place one of the test tubes containing flour extract to which no indicator was added. Use different buffer solutions until the closest possible color match is obtained.

In viewing the solutions, have a light on the side of the comparator block containing the two controls and water blank. Use north daylight if possible. If artificial light is used it must not be too brilliant and should be passed through daylight-type glass.

DETERMINATION OF FLOUR COLOR

The color of flour is of considerable significance to the baker since, on the one hand, it determines to a large degree the crumb color of the baked bread and, on the other hand, serves as at least a partial index to flour grade, effectiveness of bleach treatment, and granularity. The grade of flour is, of course, dependent upon, and is inversely related to, the content of bran and husk particles in the flour. While the color pigments of the bran are usually removed by efficient bleaching, the presence of bran tends to depress the brightness of the flour, though it may have no effect upon the primary color of the product. Natural flour also contains color pigments which impart to the unbleached product a light creamy color. In a well bleached flour, these pigments are completely decolorized. Hence, a yellowish tint in the flour generally indi-

cates inadequate bleach treatment. Granularity affects the brightness of the flour rather than its actual color. The finer the granulation, the brighter and whiter the color of the flour appears to be.

The most widely used test for flour color is the so-called Pekar test. This is actually a comparative test in which the sample whose color is to be determined is compared with a standard patent flour. The test, according to A.A.C.C. directions, is carried out as follows:

Place approximately 10 to 15 g. of the flour to be tested on a rectangular glass plate about 12 cm. long and 8 cm. wide and pack in one side by means of a flour trier or slick. Treat the same amount of a standard patent flour used for comparison in the same manner so the straight edges of the two flours are adjacent. One of the portions is then carefully moved so as to bring it into contact with the other and both are slicked with one stroke of the trier in such a manner that the thickness of the layer diminishes from about 0.5 cm. in the middle of the plate to a thin film at the edge. This should result in a quite distinct line of demarcation between the two flours so that their difference in color can be readily compared. The difference in color is then further emphasized by cutting off the edges of the layer with the slick to form a rectangle and carefully immersing the plate with the flour in cold water for 1 minute. Color is compared when the samples are still moist and after they have been dried at 100° C.

Kent-Jones and Amos (*19*) point out several criticisms of the Pekar test because its results can be influenced by the manipulation of the operator and by other factors. For example, if there is a difference in the pressure employed in preparing the flour slides, the slide with the more firmly compressed flour will appear whiter than the one with the less compressed flour. The greater pressure applied to the first slide yields a smoother flour surface which will appear whiter since it will reflect more light than will a rougher flour surface. Also, when such a slide is immersed in water, there will be less water penetration, resulting in a thinner dough skin which, again, will appear lighter than a thicker dough skin. Also, the moisture content of the flour affects the apparent color so that both the standard flour and the flour being tested must be of nearly the same moisture content. However, if sufficient care is taken to minimize or exclude these interfering factors, useful comparative results are obtained.

The Pekar test also lends itself to determining the color of a flour on a percentage basis, with the color of the standard patent flour being taken as 100 percent, and the color of a clear flour of the same type being taken at 80 percent. By mixing different proportions of these two flours,

color standards ranging from 100 percent to 80 percent are obtained with which the sample flour, which must be of the same type, can then be compared and its value expressed in terms of percentage. The proportions of the standard and clear flour required to yield the intermediary color values are shown in the following table:

TABLE 117. COLOR VALUES OF FLOUR MIXTURES

Patent Flour	*Clear Flour*	*Color Value*
g.	g.	%
20	0	100
19	1	99
18	2	98
17	3	97
16	4	96
15	5	95
14	6	94
13	7	93
12	8	92
11	9	91
10	10	90
9	11	89
8	12	88
7	13	87
6	14	86
5	15	85
4	16	84
3	17	83
2	18	82
1	19	81
0	20	80

The patent flour employed for this test should be a well bleached, high grade flour. The clear flour should be of the same type of wheat. It is important that the various flour standards be well mixed. While this test can at best yield only relative results, since neither the patent flour nor the clear flour represent fixed standards, it does permit the evaluation of flour color on a more refined scale than is possible with the simple Pekar test. In other words, it is possible with this method to establish not only any existing difference in flour color, but also the approximate degree of difference.

In addition to the Pekar color test, more complicated tests involving the extraction of the carotinoid pigments from the flour with the aid of suitable solvents, such as naphtha-alcohol, n-butyl alcohol or gasoline, and then determining the color of the extract either spectrophotometrically or colorimetrically. Detailed procedures for these various methods are published in the A.A.C.C. book of methods.

MISCELLANEOUS DETERMINATIONS

In addition to the tests already indicated, flour may be submitted to additional determinations, such as for fat and lipoid content, crude fiber content, proteolytic activity, pentosans, flour particle size, and others. None of these tests, with the possible exception of proteolytic activity, have the practical importance of the other determinations.

The fat content of flour is determined by extraction with ether, the flour fat being obtained in the form of a pale yellow oil. The endosperm portion of the wheat kernel yields slightly over 1 percent of ether extract, while the germ contains approximately 13 percent. Although the fat content of flour receives as a rule little attention as a quality factor, it does exert some effect upon the flour's baking behavior as has been shown by Johnson (*144*) and Johnson and Whitcomb (*145*). The keeping quality of the flour is limited by its fat content since the fat is subject to hydrolysis which produces rancidity phenomena within the flour. Flour stored for a long prolonged period will show the presence of free unsaturated fatty acids which, in turn, seems to determine whether a flour shall behave as young or old (*139*).

The so-called crude fiber content of flour represents primarily cellulose derived from the bran portion of the wheat kernel. It is determined by extracting the flour with ether to remove the fat, and then boiling the fat-free flour for 30 minutes in dilute sulfuric acid (1.25 percent concentration), followed by boiling for the same period in sodium hydroxide of equal strength. The treatment with acid converts the starch and other carbohydrates into soluble form, while the alkali hydrolyzes the nitrogeneous materials and other substances not affected by the acid. The organic material which then remains on an asbestos filter represents the crude fiber. Since flour, on the whole, contains only about 0.25 to 0.5 percent of crude fiber, its determination is of little significance, except perhaps in the case of long extraction flours.

The proteolytic activity of flour is of considerable importance to dough quality and elasticity. A certain amount of gluten modification is essential for optimum dough development during fermentation. Doughs lacking in proteolytic enzymes will exhibit a "bucky" character which results in low quality bread, while with excess proteolytic activity the dough soon becomes sticky unless the enzymes are inhibited by oxidizing agents, such as are present in yeast foods. Since malted wheat flour and malt extract contain relatively high quantities of proteinases, the addition of these supplements by the miller and the baker, respectively, requires considerable care if excessive proteolysis is to be avoided. A number of methods for the determination of proteolytic activity have been

developed, based on various measurements, such as of the decrease in viscosity on incubation, the quantity of amino acids liberated by proteolysis, or the ability of the material to liquefy gelatin. None of these methods have become generally accepted. The methods recommended by the A.A.C.C. include a modification of the Linderstrom-Lang method, details of which are found in Cereal Laboratory Methods (1947), and the gelation rate method of Landis and Frey (*146*).

The determination of pentosans may be carried out by two methods described in the book of methods of the A.A.C.C. They are the so-called xylene partition method and the thiobarbituric acid method, detailed directions for which are given in that volume.

Flour granulation can be accurately determined by obtaining a well-defined flour particle size separation with the aid of a mechanical shaker equipped with Tyler standard sieves and employing the procedure described by Wichser, Shellenberger and Pence (*147*). The subject of flour granulation has recently received extensive investigation by Shellenberger and co-workers (*148*) who fractionated hard wheat flour into a number of different particle size groups and compared these with respect to various properties such as ash, protein, gas production, baking response, etc. It was found that with a decrease in the size of the flour particle the ash content increases progressively to a level well above that of the original flour. The same relationship was observed with respect to protein, i.e., the protein content increases progressively as the particle size decreases, except for the finest particle size fraction (0-37 microns) which consisted essentially of free starch granules and protein matrix material (*149*).

TEST BAKING

While the various chemical and physical methods for the determination of flour quality provide useful information which frequently is adequate for the intended purpose, the baking test in which the flour is actually worked up into a dough and baked into bread on an experimental scale is generally resorted to whenever complete information on a flour's behavior in production is desired. Since the baking test is carried out under rigidly controlled laboratory conditions, the results obtained must still be interpreted in terms of the variable conditions that usually exist in large scale commercial production. The manner in which the test is to be carried out will depend on various factors. Perhaps chief among these is whether the operator subscribes to the principle on which the American or A.A.C.C. baking test is based which attempts to eliminate as much as possible the human element introduced by the operator, or

whether he prefers to exercise his skill by applying adjustments intended to develop to the full the potentiality of the flour under test. This latter procedure is followed primarily by European baking technologists.

The following equipment is specified for the A.A.C.C. baking test:

(1) A conventional experimental dough mixer of the Hobart-Swanson type, designed to mix a quantity of dough containing between 100 to 500 g. of flour.

(2) Fermentation bowls of granite ware (oatmeal bowls) having a top diameter of 14.5 cm., a bottom diameter of 5 cm., and a depth of 6.5 cm.

(3) A fermentation cabinet capable of being maintained at a temperature of 30° ± 0.5° C., and a relative humidity of at least 75 percent.

(4) Sheeting and punching machines similar to those described by Heald (*150*) or by Merritt, Markley, and Rothholz (*151*). If hand punching is resorted to, a rolling pin and a specially designed wooden track supporting a canvas belting are required.

(5) Two forms of baking pans, made of 2xx tin, and having the following inside dimensions: *Low form pans*—top: length, 11.5 cm., width 7.0 cm.; bottom: length 9.5 cm., width 5.5 cm.; depth 5 cm. *Tall form pans*—top: length 10.5 cm., width 6.0.; bottom: length 9.3, width 5.3; depth: ends 6.8 cm., sides 8.5 cm.

(6) A laboratory oven, capable of maintaining a temperature of 230° ± 5° C., and having a rotating plate or reel for carrying the pans, is recommended.

(7) A volume measuring apparatus.

Baking Procedure: The test is carried out by placing in the mixer bowl a quantity of flour equivalent to 100 g. on a 14 percent moisture basis (86 g. dry matter) and adding 25 ml. of aqueous yeast suspension, made up by dissolving 12 g. of fresh compressed yeast in water and making up to 100 ml., and 25 ml. of a salt-sugar solution made up of 4 g. of salt and 20 g. of sugar made up to 100 ml., and sufficient additional water to bring the dough to the desired consistency after mixing. If larger doughs are desired, corresponding multiples of these charges can be used according to the capacity of the mixer. Mixing is carried out for 2 minutes in a Swanson type mixer or until the proper consistency is obtained. Temperatures of the ingredients and mixer bowl should be such as to yield a final dough temperature of 30° C. After mixing, the dough is removed from the mixer bowl, scaled to an appropriate weight if a larger dough is used, rounded up by folding 20 times in the hands, placed in the fermentation bowl, and fermented in the cabinet for 3 hours. The dough is given its first punch after 105 minutes, the second punch after an additional 50 minutes and is then molded after the final 25 minutes.

Punching by the machine method is carried out by removing the dough

from the fermentation bowl, sealing over the wet side of the dough by drawing the dry edges together, elongating the dough ball slightly and passing it once through the sheeting rolls set with a clearance of $\frac{9}{32}$ inch. The dough sheet is then slightly rolled up, placed in the fermentation bowl and returned to the cabinet. In the hand method of punching, the dough is taken from the fermentation bowl, placed with its wet side down on a piece of canvas belting provided with a wooden track and,

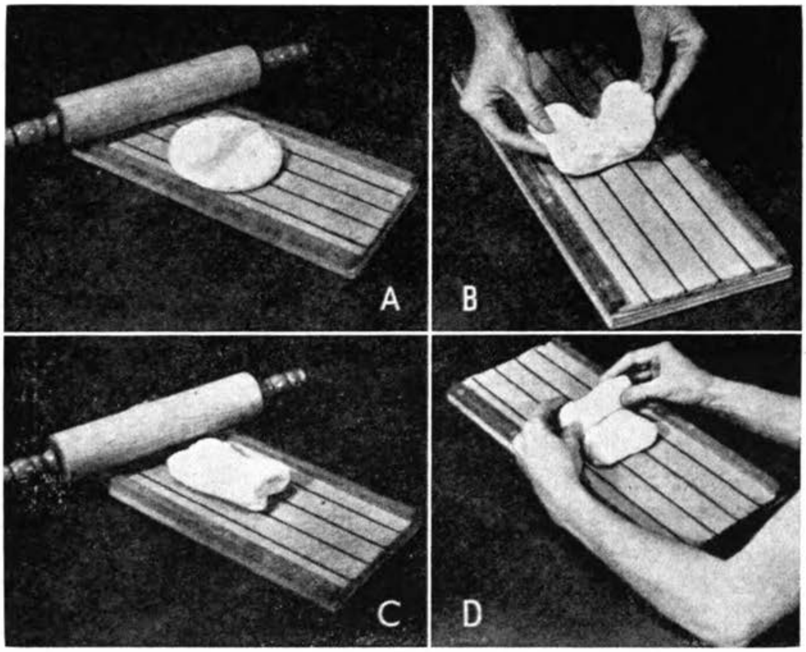


FIG. 108—Hand punching and molding technique. (*American Assoc. of Cereal Chemists.*)

with a rolling pin, rolled once each way from the center of the dough. The dough is then inverted, the opposite ends overlapped, and the dough replaced in the fermentation bowl with the seam down and returned to the cabinet. The procedure is illustrated in Figure 108 (A and B).

Moulding may be carried out by the use of the moulding machine or by hand. With the hand method the dough is first sheeted as described above for punching by hand, the dough sheet is then folded so as to have its opposite ends overlap, inverted and rolled once each way from the center. The dough is then turned over and rolled up by hand, the seam sealed, and the dough loaf placed seam down in the baking pan (*cf.* C and D of Figure 108). Care should be taken so as not to have the dough roll exceed the length of the pan. The panned dough is then proofed, either

to constant time of 55 minutes or to constant height of 9.5 cm. at a temperature of 30° C. and a relative humidity of at least 75 per cent. Baking is done for 25 minutes at a temperature of 230° C., with oven moisture provided by an open pan of water placed in the oven. If it is desired to determine the response of the flour to variations in mixing, fermentation, and oxidation, the over-all test baking procedure employed is essentially the same as described, except for changes in lengths of mixing time and fermentation time and of bromate level, respectively. The resulting loaves are weighed and their volume determined 1 hour after removal from the oven. They are subsequently scored for their external characteristics, crust color and symmetry, and their internal characteristics, crumb color, grain and texture.

In addition to the standard baking test developed by the A.A.C.C., there are, of course, a great many other procedures used by different plants and laboratories, each designed to yield reproducible results and to reveal the desired information with regard to the flour and the various other ingredients employed. Test baking procedures as applied in Great Britain and other European countries have been described in detail by Mounfield (*152*) and by Kent-Jones and Amos (*19*).

BREAD SCORING

Both the loaves obtained in experimental baking tests and those produced in commercial baking are subjected to regular evaluation or scoring to determine their physical characteristics on a comparative basis. The individual characteristics of the loaf are related to those of a hypothetical standard loaf. Since scoring is based largely upon personal judgment in which the scorer visualizes an ideal loaf with which he compares the loaf under evaluation, it is obvious that no absolute values can be established. Different regions may show different preferences in bread characteristics so that even the scale of scoring may lack uniformity. In general, a typical scoring card for standard white bread may have the point values shown in Table 118 assigned to the various loaf characteristics which are covered by scoring.

While on this score card nine loaf properties are evaluated, this number may be increased by including break and shred as one characteristic and by evaluating color of crust separately from character or nature of crust. Also, the relative point value of some of the characteristics may be changed to bring them into closer conformity with varying emphases encountered in different regional markets with regard to the different loaf properties. Thus, for example, texture and aroma are in some regions considered by the public to be of greater importance than volume. The point values assigned to texture and aroma might in this instance

be justifiably greater than shown on the average score card, while the point value assigned to volume might be correspondingly reduced.

Volume is the space occupied by the loaf. There is generally an ideal relation between dough weight and volume which yields the most desirable texture and grain. The volume, expressed in terms of cc. or cubic in., is usually determined by the seed displacement method in which the loaf is placed in a container into which small seeds, e.g., poppy seed, are run until the container is full. The volume of seeds displaced by the loaf is either directly indicated or may be calculated. Volume may be either too large, too small, or satisfactory. An excessively large volume

TABLE 118. TYPICAL BREAD SCORE CARD

Volume	15
Color and nature of crust	5
Symmetry of form	5
Uniformity of bake	5
Texture	15
Color of crumb	10
Grain	10
Aroma	15
Taste	20
Total	100

is usually accompanied by an open grain and a weak texture. A small volume may be due either to poor gluten quality or to improper fermentation, as when there is insufficient gas development to provide proper dough expansion, or when the dough is not properly matured. The concept of volume also includes the factor of loaf shape, i.e., the length, width and height should all be in a pleasing relationship.

Crust color, often referred to as bloom, should normally shade from a deep golden brown on the top to a light golden brown on the sides of the loaf. The crust color is dependent largely upon the temperature at which the bread is baked and upon the amount of residual sugar in the dough when baked. Given normal baking temperatures excessive amounts of sugar will usually lead to a crust color which is either too dark or possesses a foxy-red appearance, the latter color being generally caused by the presence of unfermented sucrose. A pale or grayish crust color indicates an inadequacy of residual sugar, which may be due to over-fermentation, lack of diastatic activity in the dough, or omission of sugar in the formula.

While the color of the crust has lost some of its former significance of eye appeal with the extensive adoption of bread wrapping, especially when opaque wrapping material is used, the character or nature of the

crust is still important as a factor in the consumer acceptance of the product. Consumer preference is for a thin, tender crust. Wrapping, while it protects the loaf against rapid moisture loss and may also partially hide defects in crust color, imposes a severe strain upon the crust. A crust which might prove acceptable in an unwrapped loaf can readily become tough and leathery under the influence of moisture condensation that takes place at the surface of the wrapped loaf. Tenderness of crust is obtained by the use of appropriate amounts of shortening and sugar, and by correct fermentation. Over-fermentation tends to produce a pale, brittle crust, and under-fermentation a dark, tough, leathery crust. Oven conditions also affect crust character. Thus a cold oven normally yields tough crusts with a dull color; excessive oven steam also produces a tough, leathery crust with a highly glazed appearance; improper heat distribution will give rise to an uneven thickness in the crust.

Break and shred are terms that refer to the rupture in the crust that occurs along the top sides and ends of the plain top loaf during oven spring, and the vertical streaking that appears on this rupture, respectively. Break and shred are of importance to the appearance of the loaf, with even shredding and a uniform break being desirable. In the split top loaf, the shredded break will be through the center of the top and at the ends. So-called wild breaks at the sides or ends, or breaks without shred detract materially from the eye appeal of the loaf.

Symmetry of form is of significance not only because an attractive loaf shape exerts a definite eye appeal but also because it indicates that the loaf has been properly proofed and has shown a good oven spring. Loaf defects that detract from symmetry of form include improper loaf dimensions, such as loaves being too wide or too narrow for their height and length due to faulty pan design; flat tops caused by weak gluten; protruding sides or ends; and sharp corners.

Evenness of bake is of obvious importance to bread quality. A loaf which has a thick dark top crust, while its sides and bottom are pale and underbaked, is evidently unacceptable. The reverse, namely scorched bottom crusts and pale top crusts, which result from excessive bottom heat, is equally objectionable. The ideal loaf will possess a crust of uniform thickness and with its golden color varying over only a limited range.

Crumb color is determined visually by examining closely the color of the loaf interior after slicing. The color depends chiefly upon the natural color of the endosperm of the wheat and of the bran particles present in the flour. Since bran possesses a marked coloring effect, its proportion in the flour will affect the color perceptibly so that a straight flour, for example, will fail to produce as bright a crumb color as will a patent

flour, all other factors being equal. In practice, however, crumb color is affected also by the grain of the crumb, the finer the grain, the brighter the color. Grain, again, is seldom uniform throughout the loaf, being generally finer and more even at the ends than at the middle of the loaf (*152*), so that a comparison of crumb color between two loaves should be made on portions cut at the same part of the loaves. Color evaluation should be made on freshly cut surfaces, since the crumb tends to darken somewhat on exposure of its cut surface. The most desirable crumb color is a soft creamy white, free from streaks or spots.

The *grain* of the crumb represents its porosity or cell structure, being constituted of the size, shape and distribution of the gas cells. A desirable grain is composed of small cells of uniform size and slightly oval shape, with thin cell walls. Most of the terms used to characterize grain, such as close, uniform, open, coarse, and wild, are sufficiently descriptive to require further elucidation. Generally an open grain with thick cell walls indicates inadequate gluten development or a weak gluten, while holes can be frequently traced to faulty moulding, although no general agreement exists as to the actual causes of holes in bread.

Crumb texture represents the degree of elasticity or softness of the crumb. Since it is closely associated with the character of the grain, it is frequently confused with the latter. A further source of confusion is the fact that in British baking terminology, texture does actually refer to grain, while what we refer to as texture is termed softness. Texture is determined entirely by the sense of touch. The fingers are pressed lightly against the cut surface of the loaf and rubbed across the grain. The sensation produced by the crumb may be described as velvety, silky, soft, elastic, or rough, harsh, crumbly, lumpy and doughy, as the case may be. Obviously the finer the cell structure and the thinner the cell walls, the softer and more elastic will be the texture. Conversely, an open, coarse grain is usually associated with a rough, harsh texture.

Aroma is the quality determined by the sense of smell. To determine bread aroma, the loaf is held close to the nose and then air squeezed out of it during the act of smelling. Since aroma constitutes an important component of bread flavor, it is obvious that it must appeal to the consumer and must therefore be adjusted to coincide with the prevalent preferences within the market area supplied by the baker. The aroma may be wheaty, nutty, malty, sweet, sour, or musty, moldy, ropy or rancid.

Taste constitutes the second major constituent of flavor. It is the characteristic determined by the taste buds of the tongue and mouth membrane and refers, strictly speaking, only to the sensations of sour, salty, sweet and bitter. Actually, the average consumer does not dis-

tinguish consciously between taste and aroma, but reacts subjectively to their combined effect, which is flavor. Bread usually has a slightly sweet-sour taste, although it may acquire also distinctly acid and rancid tastes. Part of the taste sensation includes also the chewing quality of the bread. The bread mass should break down easily in the mouth on mastication, without forming doughy lumps that are difficultly wetted by the saliva and swallowed. Actually, in the over-all evaluation of the eating quality of bread all the various characteristics, such as texture, aroma, taste, and chewing quality, play their distinctive roles.

PART IV—ASPECTS OF CAKE BAKING

CHAPTER XXII

CAKE INGREDIENTS

Any discussion of cake ingredients, in a general text on baking, must necessarily be fragmentary if repetition of much basic information pertaining to bakery raw materials as a whole is to be avoided. Thus the majority of cake ingredients, such as flour, eggs, milk, salt, sugar, shortening, etc., are either identical to, or differ only in minor aspects from ingredients employed in the production of yeast-raised products. Actually, the two principal groups of materials necessary to cake baking which do not find application in the production of yeast-raised goods are chemical leavening agents and certain spices and flavors. Hence on the following pages there will be briefly discussed those ingredients which differ in some respects from their counterparts in bread baking, such as flour and shortening, as well as those ingredients not normally encountered in breadmaking, such as chemical leaveners and flavors. For information about the remaining materials and products, such as sugar, eggs, milk, salt, etc., the reader is referred to the specific chapters in which these are dealt with in greater detail.

CAKE FLOUR

Although wheat flour is discussed in some detail in Chapter VIII, a brief review at this point of the special requisites of cake and cookie flours will prove desirable.

Cake flours are normally milled from soft winter wheat varieties which possess relatively low protein contents. The soft red winter wheats of the Midwest are largely used for this purpose, sometimes blended with soft white varieties. The soft wheat varieties grown in the Pacific Northwest of the United States also have proven very satisfactory, as have still other soft varieties grown in Colorado, Idaho and Missouri. These flours, to give satisfactory performance in cake production, must be capable of forming a soft yielding gluten which does not develop a significant degree of toughness during cake mixing. On the other hand, the gluten must possess sufficient strength and be present in an adequate amount to assure the formation of a fine cellular structure in the cake. Experience has shown that the very short patent flours from soft wheats yield superior tenderness and softness of texture as compared to lower grades.

Cake flours, therefore, have ash contents within the range of 0.34 to 0.38 percent and protein contents of 7.0 to 9.0 percent. Because of the low content of soft gluten, cake flours also have a relatively low absorption, values of the order of 54 percent being not uncommon.

Absorption, in the case of cake flour, is not synonymous with the term used with bread flours. Bread flour absorption is largely governed by protein content and gluten strength, two factors of the greatest importance in bread production, but of relatively minor significance in cake making. Absorption in cake flours implies their liquid-carrying capacity, which should be as high as possible. High liquid-carrying capacity, coupled with the ability to retain moisture in the finished cake, appears to be associated with a number of other cake flour properties, several of which are directly controllable by the miller. These include protein content, maturing treatment, and granulation.

As has been indicated above, cake flours should be of low protein content. Unlike in a bread dough, gluten plays a relatively minor role in a cake batter as far as providing a framework is concerned. High protein flours result in tough eating cakes. As a general rule, the lower the protein content the more tender the finished product will be. However, there must be a proper balance between flour strength and the weight in other ingredients the flour is expected to carry. In other words, the particular flour selected for a specific type of cake must possess a sufficient protein content to form enough gluten to hold the finished cake together and to form the final cellular crumb structure. The aim should therefore be to select a flour with a protein content just high enough to meet the given gluten requirement, since such a flour will normally yield the most tender product. Thus, while a flour with a protein content of 7 percent would under normal conditions be considered highly desirable for angel food cakes, in which egg white, present in high proportion, supplies additional structural protein for the formation of the cell structure, it would lack sufficient strength to be suitable for heavier types of cake, such as most kinds of fruit cakes. On the other hand, a flour with a sufficiently high protein content to perform satisfactorily with heavier types of cake would produce an excessively tough foam type cake. Cathcart (*153*) suggests that flours for high-sugar cakes have a protein content of 7.5 to 8.5 percent; flours for the heavier cakes, 8.5 to 9.5 percent; and cookie flours, 8.0 to 9.0 percent. In general, patent cake flours of 40 to 50 percent extraction are recommended for use in foam type cakes.

The maturing or bleaching treatment given a cake flour is an important factor in determining quality. The standard bleaching agent employed for cake flours is chlorine, used at times in conjunction with 1 percent nitrosyl chloride. One of the effects of chlorine is a reduction of the pH

of the flour, i.e., chlorine treatment results in an increased flour acidity. The pH of a cake flour, therefore, constitutes a partial index to the degree of chlorine treatment. It is, however, also dependent upon another variable, namely, the extraction of the flour. Cake flours of high ash content require more chlorine treatment to mellow the gluten and produce a given pH than do flours of lower ash content. Thus, as Dalby (*154*) points out, a cake flour with 0.38 percent ash and a pH 5.0 has received a more drastic chlorine treatment, and consequently will yield a softer gluten, than a cake flour with 0.32 percent ash and a pH of 5.0. Practical experience has shown that best flour performance is obtained when it is carefully bleached to a pH value within the range of 5.0 to 5.3. The pH of unbleached soft wheat flour generally falls within the range of 5.8 to 6.1. The improving action of the chlorine bleach is not solely attributable to a lowering of the pH or the removal of coloring matter, but perhaps to an even greater extent to the mellowing action upon the gluten proteins, whereby the toughening tendency of the flour is reduced. Chlorine also acts to make the starch somewhat more soluble, increasing its moisture absorption and retention capacities (see Figure 33).

While the bleaching of cake flours is more or less essential to ensure good baking performance, cookie flours are harmed by a bleach treatment and are generally used unbleached. Thus Shellenberger (*155*) has shown that the suitability of a soft wheat flour for cookie production is progressively reduced with an increasingly drastic bleach treatment. By treating portions of the same flour with various amounts of chlorine, samples with progressively lower pH values were obtained. A series of cookies were baked under identical conditions from each of the samples. The effect of pH on the spread and thickness of cookies is shown in the following table.

TABLE 119. THE EFFECT OF THE pH VALUE ON THE SPREAD OF COOKIES

pH of Flour	Average diameter mm.	Average thickness mm.	Ratio of diameter to thickness
5.88*	818	114	7.17
5.75	758	146	5.29
5.43	748	152	4.92
5.13	718	162	4.43
4.87	706	168	4.21

* Unbleached samples

It will be noted that as the pH of the flour changes in the direction desirable for cake production, the cookies become smaller and thicker, and yield progressively lower ratios of diameter to thickness.

Granulation of cake flour also plays an important role in its over-all behavior. The finer and more uniform the granulation, the better the results obtained with the flour. At present, general mill practice is to finish cake flour through 14 XX silk bolting cloth. Just what the relation is between the fineness of granulation and cake making properties, aside from the possibility that such fine reduction of the flour particles facilitates their dispersion in the cake mix, is not definitely known.

A test which is frequently applied to cake flours is the viscosity test. Briefly, this test consists of making a smooth suspension of 20 grams of flour in 100 cc. of distilled water, placing this suspension in the cup of a MacMichael viscosimeter, and reading the viscosity with the disc bob suspended on a No. 20 wire and the cup revolving at 12 rpm. Readings are taken on the untreated suspension, after 1 cc. or normal lactic acid solution has been added, and then three more times following as many additions of 2 cc. of acid. The rate of increase in viscosity provides an insight into the extent to which the flour is buffered and may be taken as an approximate index of grade. The final viscosity, which usually is also the maximum viscosity reading, is regarded as the index of strength.

Most cake flours yield viscosities of approximately 40° to 50° MacMichael. Garnatz (*156*) points out, however, that the range may extend from a minimum of 12° to a maximum of 70° MacMichael, with satisfactory cake baking performance. Flours with viscosity values higher than 70° MacMichael are usually predisposed toward a certain harshness in grain and texture of the cake. In view of the wide range of viscosity values within which satisfactory cake is produced, this test obviously falls short of giving a close correlation between its results and the cake making properties of the flour being tested. At best, it provides an evaluation only along very general lines.

In the final analysis the suitability of a cake flour is most accurately established by a cake baking test. In general, the most reliable procedure is to employ the type of formula for which the flour under test is intended since no one type of cake is an all-inclusive medium for test baking. Thus a flour that produces the best yellow layer cake will not necessarily perform with equal excellence when used for pound cake. If, however, it is necessary to restrict the test to a single type of cake, then, according to Garnatz (*157*), the white layer variety comes closest to providing for most conditions.

SHORTENING

Fat performs several important functions in all cake products in which it is used as a basic ingredient. These functions include the entrapment of air during the creaming process, resulting in the proper aeration or

leavening of the batter and finished cake; the lubrication of the gluten and starch particles, breaking thereby the continuity of the gluten and starch structure that comprises the cell walls and making the crumb tender; and the emulsification and holding of considerable amounts of liquid, increasing and prolonging the softness of the cakes.

While it is possible to obtain a satisfactory cellular structure without fat in yeast-leavened products and in foam-type cakes, other types of cake require fairly large proportions of shortening for the development of their characteristic structure. While the exact mechanism involved in the leavening process still requires study for complete clarification, both experimental tests and microscopic observations have very definitely established the vital function of fat in the leavening of batters and cakes. From a colloidal viewpoint, cake batters or doughs are emulsions consisting of an internal phase comprised of the fat and an external phase made up of the remaining ingredients. Cake batters are the result of the mixing together of certain dry ingredients, such as flour, sugar, salt, baking powder, fat, etc., with the liquid ingredients milk and egg. The sugar, salt, and baking powder will dissolve in the liquid ingredients and the resulting solution will mix freely with the flour. No such intimate absorption of the fat occurs. If a cake batter, made up with fat to which a small amount of oil-soluble dye has been added, is examined under a microscope it will show the fat to be dispersed throughout its mass in the form of small, irregularly shaped discrete particles, the degree of dispersion depending largely upon the amount of mixing to which the batter has been subjected. Hence the fat occurs as a distinct phase in the batter, which is actually an emulsion of the oil-in-water type. The fact that the fat appears in the batter in the form of irregularly shaped particles rather than as spherical droplets, as is usually true of the oily phase of an ordinary emulsion, is attributable to the plastic, instead of liquid character of the shortening. If these fat particles are closely examined, it will be seen that they enclose numerous minute air bubbles or cells which have been incorporated during the mixing process. At the same time, an examination of the external or aqueous phase will show it to be free of air bubbles. Hence, in batters containing a fair proportion of shortening, aeration during the mixing process is an exclusive function of the fat.

Dunn and White (*158*, *159*), in studying the leavening action of air in pound cake production, have found that the amount of air incorporated into the cake batter determined the volume of the finished cake. Their tests were carried out with pound cakes containing no baking powder. In pound cake production, using the creaming process, the sugar and shortening are creamed together for approximately 5 minutes, when the eggs are gradually added and creaming is continued until a light foamy

mixture results containing a considerable amount of incorporated air. At this stage the mixture consists of a water-in-oil emulsion and an air-in-oil foam, according to the findings of Grewe (*160*). By determining the weight of a known volume of this creamed mixture, it is possible to calculate its specific volume, which is the reciprocal of the specific gravity. The same procedure may also be applied to determining the specific volume of the finished batter containing the remaining ingredients. By measuring the specific volumes of the creamed mixture and of the batter, as well as the volume of the finished cake, it is possible to evaluate fairly accurately the creaming quality of a shortening and thus determine its suitability for cake baking. In the following table are given some typical data for a number of characteristic shortenings.

TABLE 120. TYPICAL POUND CAKE DATA
(From Dunn and White, 1937)

Shortening	Specific volume of cream	Specific volume of dough	Cake volume in cc.
1	1.88	1.39	3,023
2	1.67	1.38	3,000
3	1.81	1.26	2,633
4	1.61	1.18	2,494
5	0.93	0.90	1,700

Shortening 1 represents a high-quality shortening well adapted for icings, cakes and general bakery production. No. 2 represents a shortening with good cake-making properties but deficient in creaming volume. No. 3 represents an average shortening in the general baking field. No. 4 represents a typical compound and No. 5 is a prime steam lard. The numerical data show that high creaming volume is usually, but by no means always, associated with high batter volume and high loaf volume and also that a shortening may be deficient in creaming property and yet produce high loaf volume. The relation of batter volume to loaf volume is very much closer.

These results clearly underline the fact that the most reliable and accurate procedure for determining the creaming value of a shortening is to actually prepare a pound cake batter without baking powder, bake the cake and measure its volume per unit weight. However, to be reproducible, the test must be carefully standardized, particularly with respect to temperature which has a marked effect on creaming value. Since most mixing rooms do not provide for temperature control, the temperature of the batter may undergo considerable seasonable variation so that it is important for the shortening to have good creaming qualities over the

range of temperature that is likely to prevail. Crapple (*161*) suggests that a good approximation of the creaming value at any temperature can be obtained by adjusting the temperature of the batter by placing the mixing bowl in a water bath while the batter is being mixed.

Aside from the character of the shortening, the conditioning which the shortening received prior to use was found also to exert a marked effect upon its baking characteristic. Thus Dunn and White (*158*) took three shortenings, two all-hydrogenated and one soft compound, and divided each into three sub-samples. One set was conditioned at 50° F. for 100 hours and then at 70° F. for 100 hours. The second set was held at 70° F. for 200 hours and constituted the control. The third set was conditioned at 90° F. for 100 hours, and subsequently at 70° F. for 100 hours. The pound cake data are reproduced in the following table.

TABLE 121. EFFECT OF PREVIOUS STORAGE TEMPERATURE ON BAKING VALUE OF SHORTENING

Temperature conditions to which shortenings were subjected	Stored at 50° F. 100 hours, then at 70° F. for 100 hours			Stored at 70° F. for 200 hours			Stored at 90° F. for 100 hrs., then at 70° for 100 hours		
Shortenings	Sp. vol. of cream	Sp. vol. of dough	Loaf vol. in cc.	Sp. vol. of cream	Sp. vol. of dough	Loaf vol. in cc.	Sp. vol. of cream	Sp. vol. of dough	Loaf vol. in cc.
All-hydrogenated shortening "A"...	1.87	1.31	2,708	1.87	1.32	2,765	1.85	1.31	2,689
All-hydrogenated shortening "B"...	1.81	1.28	2,709	1.85	1.31	2,734	1.82	1.29	2,647
Soft compound.....	1.79	1.28	2,656	1.81	1.31	2,609	1.76	1.24	2,354

These data show clearly that previous storage conditions exert a definite effect upon the baking characteristics of shortenings. Either too warm or too cold storage exert a deleterious effect upon quality. Warm storage conditions are particularly undesirable for soft-bodied shortenings.

Good creaming quality, contrary to the general impression, is not restricted to any one particular type of shortening. Thus lard, which is generally considered to possess the poorest creaming value of commonly used baking fats, may be endowed with excellent creaming qualities and a superior working range if hardened with lard flakes and properly processed.

The second important function of shortening in cake baking is the imparting of shortness or tenderness to the cake crumb. This the shortening accomplishes by coating the starch and gluten particles which form

the cellular structure of the crumb with a film of fat, thereby preventing a continuous structure, with its inherent toughness. The shortening in effect creates numerous points of weakness within the structural framework of the crumb. The degree of tenderness imparted to cake by a shortening depends partly upon the quantity of fat introduced and partly on the degree of dispersion obtained on mixing. It has been found that the shortness of a cake crumb increases markedly as the fat content is increased up to a certain point, after which further additions of fat bring about reduced effects on cake tenderness, until the practical limits of fat addition are reached. It has also been observed that fats which disperse in a batter in a fine pattern exert a greater shortening effect than do fats which emulsify less completely. Thus the superior shortening effect of lard is largely attributable to its fine dispersal pattern which, according to Carlin (*162*), is somewhat similar to that obtained with high-emulsifying shortenings. Lards which have been modified either in composition or physical texture so as to resemble regular hydrogenated shortenings show a reduction in shortening power. This property is also improved by the use of mono- and diglycerides and other emulsifying agents which function to aid the dispersion of the fat in the batter.

The emulsification value of a shortening may be defined as its ability to make a white layer cake in which the flour content is low and the sugar and moisture contents are high. The problem is to produce a good emulsion of the batter ingredients that will possess sufficient stability to yield a cake of good volume. One of the original functions of eggs used in cakes was to serve as an emulsifying agent since it was observed that the addition of egg yolk in particular promoted the dispersion of the fat. Actually, the active emulsifying agent of egg yolk is lecithin and a similar effect is obtained by the use of soybean lecithin. The addition of mono- and diglycerides to shortenings, resulting in so-called superglycerinated shortening, greatly increases their emulsification value. Such fats are the typical high-emulsifying cake shortenings of today which make possible the production of modern high sugar, high moisture cakes. The best method for determining the emulsification value of a shortening is to make a high-sugar white layer cake under standard conditions, using the volume per pound of the finished cake as the criterion of value, and noting also the appearance of the batter, crust characteristics, grain, and texture. According to results obtained in one laboratory (*161*), shortenings without added emulsifying agents give separated batters and cakes having volumes of 1,150-1,200 cc. per pound, sticky crusts, and a raw flour taste. Good superglycerinated cake shortenings will produce cakes having volumes of 1,300-1,400 cc. per pound, with satisfactory top crusts, fine grain and texture and eating qualities.

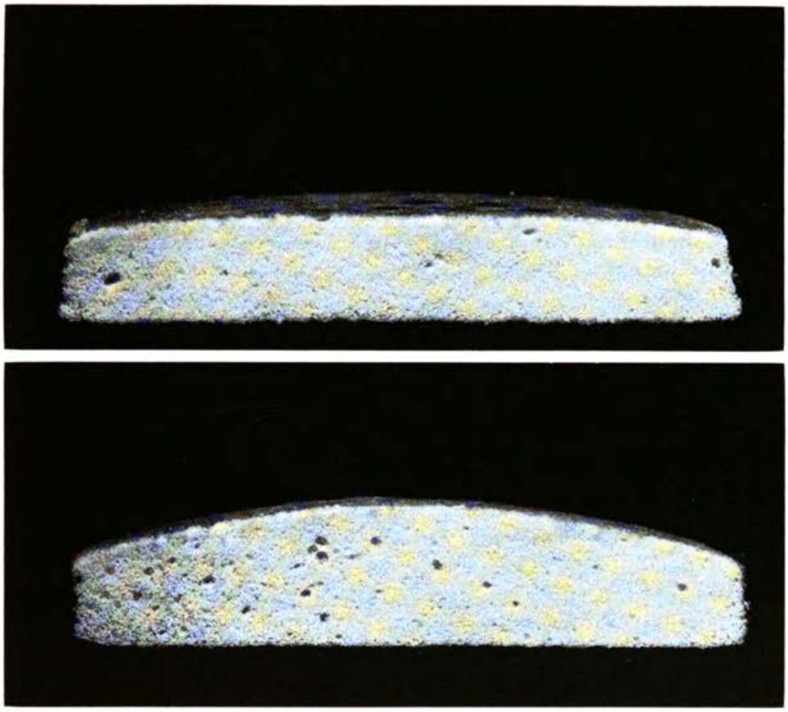


FIG. 109—Effect of shortening type on white cake volume. Regular shortening was used in cake shown in upper photo, emulsifier type shortening in cake in lower photo. (*Courtesy Procter & Gamble Co.*)

The ability of a shortening to take up and hold water is considered important in the making of certain types of cream fillings, although its practical value in cake making appears to be of little significance since no differences in cake batters made with fats of different water absorbing capacities can generally be observed. This property can be readily measured by slowly adding water to the shortening while it is being creamed in a laboratory mixer until the fat will no longer take up water, a point that is easily recognized. Different fats vary considerably in their water absorbing capacities. Thus superglycerinated fats will give values up to 800 percent based on weight of fat used, while lard will usually absorb 25 to 50 percent, and all-hydrogenated shortening will take up 150 to 200 percent. In general, the shortening with the higher water absorption will yield the lighter icing.

CHEMICAL LEAVENING AGENTS

The function of leavening agents is to aerate the batter and thereby render it light and porous. The porosity of the batter, which on baking

is transferred to the finished cake, is of importance for a variety of reasons: It is responsible for good volume; it improves eating quality by tenderizing the crumb; it contributes to the aesthetic enjoyment of the final product by imparting to it certain properties, such as uniformity of cell structure, brilliance of crumb color, softness of texture, enhanced palatability, etc.

Leavening may be produced by a variety of means. Thus yeast, in the fermentation of bread and sweet doughs, generates carbon dioxide gas through its biological life activities. One may thus speak of yeast fermentation as a process of biological leavening. Other microorganisms, in addition to yeast, are capable of producing carbon dioxide gas as one of the end-products of their metabolitic function and are for this reason used in baking. As examples may be cited the bacteria constituting the microbial flora of salt-rising bread and the lactic and acetic acid bacteria of the sour doughs in rye bread production. A second important means of leavening is of a purely mechanical nature and involves the incorporation of air into the doughs and batters by creaming and mixing actions. The importance of this type of leavening in bread baking is of considerable magnitude in an indirect way, for Baker and Mize (*163*) have shown that yeast is incapable of originating gas cells in a dough. There must exist preformed gas cells, incorporated mechanically by the action of the mixer, into which the carbon dioxide gas generated by the yeast can diffuse. Bakers are generally more familiar with mechanical leavening as it applies to the production of various types of cakes. Thus, such cakes as pound cake, sponge cake and angel food cake can be, and are being made without the addition of leavening agents by insuring adequate aeration of the batter or sponge during its mechanical treatment in the mixing bowl. The application of heat during baking also results in a form of leavening which may properly be designated as physical since it is caused by such purely physical forces as the expansion of gases in the air cells of the batter under the influence of heat and the formation of water vapor, all of which act to increase the volume of the batter.

The principal means of leavening in cake baking, however, is so-called chemical leavening obtained by the use of baking powders which, on contact with liquid, react chemically to yield carbon dioxide gas in controlled volumes and frequently at a controlled rate of gas evolution. Chemical leaveners other than baking powders are also used to a limited extent in the production of biscuits, crackers and cookies. Included among these less important leaveners are sodium bicarbonate ($NaHCO_3$), also called baking soda, which depends upon the presence of acidic ingredients, such as buttermilk, sour milk, molasses, honey, etc., to release its carbon dioxide, and ammonium carbonate and bicarbonate which on

the application of heat decompose into ammonia, carbon dioxide and water (*164*).

It is believed that the earliest efforts to obtain efficient chemical leavening involved the use of sodium bicarbonate and sour milk (*165*). A great number of both alkaline and acidic compounds were suggested and used for leavening purposes beginning at about the middle of the last century, and several of the currently used acids or acid reacting salts were first introduced at that time.

At present the composition of baking powders must conform to the following general definition first issued by the Federal Government in 1918 and subsequently revised and clarified (*166*):

> "Baking powder is the leavening agent produced by the mixing of an acid reacting material and sodium bicarbonate, with or without starch or flour. It yields not less than twelve percent of available carbon dioxide. The acid reacting materials in baking powders are: (1) Tartaric acid or its acid salts; (2) Acid salts of phosphoric acid; (3) Compounds of aluminum, or (4) Any combination in substantial proportions of the foregoing."

It will be noted that this advisory standard is specific in designating sodium bicarbonate as the only permissible alkaline ingredient of baking powders, and further in setting a minimum limit of 12 percent available carbon dioxide based on the weight of the product. With respect to the acid ingredient, it permits a wider selectivity of acids and acid reacting salts, thereby providing for the manufacture of baking powders possessing markedly different properties.

It should perhaps be pointed out that the standard for baking powder is not quite as rigid as may appear at first sight, since subsequent clarifications (*167*) allow the use of other harmless substances that may be suitable for the purpose, with the stipulation that if any substance that is not included among those mentioned in the definition is used in a baking powder, this fact should be plainly stated upon the label so that the purchaser will be fully informed.

Baking powders may be classified according to their acid-reacting components into tartrate powders, phosphate powders, and combination powders. Depending on their rate of reaction, baking powders are also commonly designated as fast acting, slow acting, or double acting. The so-called fast acting powders release most of their gas volume during the first few minutes of contact with liquid and therefore require fairly rapid dough or batter handling if excessive volume loss is to be avoided. The slow acting powders release practically none of their gas volume at low temperatures, requiring the heat of the oven to effect complete reaction and full evolution of the carbon dioxide gas. A so-called double

action powder, as the name implies, reacts partly at low temperatures to form sufficient gas for a smooth flowing batter, but requires elevated temperatures for complete reaction. It is this last type of powder, formulated by the manufacturer to yield a uniform, regulated action, that is most widely used in cake baking. Whether a powder is fast acting or slow acting depends upon the solubility of the acid-reacting component in cold water. If the acid component is soluble at room temperature, it forms the basis of a fast acting powder, whereas if it is insoluble in cold water it renders the powder slow acting, i.e., principal evolution of carbon dioxide occurs only at elevated temperatures. In double action powders belonging to the category of combination powders, one of the acid ingredients is cold water soluble, while the remaining and quantitatively usually predominating acid components are soluble only at high temperatures and hence react at a rapid rate after reaching the oven. The difference in the rate of carbon dioxide liberation from baking powders containing one acid reacting component and treated with water at 77° F. is shown in the following table by Holliday and Noble *(168)*:

TABLE 122. GAS EVOLUTION

Acid Reacting Component	Total carbon dioxide	Carbon dioxide liberated in 2 min. by water	Carbon dioxide liberated in 15 min. by water
	% by weight	% by weight	% by weight
Tartaric acid	14.0	13.8	14.0
Cream of tartar	14.0	10.6	13.8
Monocalcium phosphate	14.0	8.6	9.3
Sodium Aluminum Sulfate	14.0	3.2	6.2

In the formulation of baking powders it is important that the quantitative balance of alkaline and acid-reacting ingredients be such as to bring about complete neutralization of the sodium bicarbonate and acid ingredient so as not to leave any residue of either ingredient in the finished product. The following theoretical quantities of sodium bicarbonate are required to neutralize 100 parts of the respective acid ingredients and these ratios may be employed as guides in the formulation of baking powders *(167)*: Cream of tartar, 44 parts of sodium bicarbonate; tartaric acid, 116 parts; monocalcium phosphate, 80 parts; sodium aluminum sulfate, 104 parts; sodium acid pyrophosphate, 75 parts.

The Government standard for baking powders specifies that the product must yield not less than 12 percent of available carbon dioxide. Most commercial powders, however, yield from 14 to 17 percent, thus providing a margin of safety of 2 to 5 percent against possible loss of

strength during storage. In addition to the reactive components, baking powders also contain an inert filler which is usually specially treated corn starch and which performs two useful functions: (1) It stabilizes the product by keeping the active ingredients apart and thereby preventing their mutual reaction in case moisture should find access to the product; and (2) it serves as a standardizing agent in establishing the strength of the powder. Recently, part of the starch filler has been replaced by powdered calcium carbonate in some commercial products (*169*).

Cream of tartar and tartaric acid baking powders constitute fast acting powders, the reaction between the components occurring at low temperature in the presence of moisture to liberate the carbon dioxide. A representative formula for this type of powder contains 26.73 percent sodium bicarbonate, 5.97 percent tartaric acid, 44.90 percent potassium bitartrate (cream of tartar) and 22.40 percent corn starch (*167*). The reaction between the cream of tartar and the bicarbonate is the following:

$$\underset{\substack{\text{Potassium}\\ \text{bitartrate}}}{KHC_4H_4O_6} + NaHCO_3 \rightarrow CO_2 + \underset{\substack{\text{Potassium}\\ \text{sodium tartrate}}}{KNaC_4H_4O_6} + H_2O$$

Tartaric acid reacts rapidly with soda to yield carbon dioxide and for this reason finds very limited use as a baking powder ingredient, being used as a minor additive in tartrate powders. Its reaction with sodium bicarbonate proceeds as follows:

$$\underset{\substack{\text{Tartaric}\\ \text{acid}}}{H_2C_4H_4O_6} + NaHCO_3 \rightarrow \underset{\substack{\text{Sodium}\\ \text{tartrate}}}{Na_2C_4H_4O_6} + 2CO_2 + 2H_2O$$

Phosphate powders are of three kinds. The earliest to be developed used monocalcium phosphate. A typical composition of such a baking powder would contain 26.73 percent sodium bicarbonate, 33.43 percent monocalcium phosphate and 39.84 percent corn starch. The reactions between the acid and alkaline ingredients are slightly more complex, differing with changing conditions, although the following equation probably indicates best the reaction occurring under ordinary circumstances:

$$\underset{\substack{\text{Monocalcium}\\ \text{phosphate}}}{3CaH_4(PO_4)_2} + 8NaHCO_3 \rightarrow \underset{\substack{\text{Tricalcium}\\ \text{phosphate}}}{Ca_3(PO_4)_2} + \underset{\substack{\text{Disodium}\\ \text{phosphate}}}{4Na_2HPO_4} + 8CO_2 + 8H_2O$$

The residue of the reaction consists of two salts, tricalcium phosphate and disodium phosphate. Monocalcium phosphate reacts rather rapidly

with sodium bicarbonate at slightly elevated temperatures and can be considered as a fast acting powder. This fast action was one of the reasons for the failure of this baking powder to gain wide acceptance, although it also had the further drawback of causing the appearance of dark specks on the surface of baked products, especially pie crusts and biscuits.

With the introduction of anhydrous monocalcium phosphate as an acid ingredient for baking powders in 1939, a slow-acting powder of the monocalcium phosphate type became available. This new phosphate consists of minute crystals which, on being subjected to a special heat treatment, assume an "autogenous, glass-like, substantially water-insoluble coating" (*170*) which protects the product against decomposition in moist atmospheres and retards its interaction with sodium bicarbonate in the presence of water at low temperatures.

Sodium acid pyrophosphate, because of its relative insolubility in cold water, forms the acid constituent of a slow acting baking powder. A representative formula of such a baking powder would include 30.59 percent soda, 40.38 percent sodium acid pyrophosphate and 29.03 percent corn starch, and yield approximately 17 percent of total carbon dioxide. Reaction between the sodium acid pyrophosphate and soda is thought to yield a mixture of normal sodium pyrophosphate and disodium phosphate, according to the following equations:

$$\underset{\text{Sodium acid pyrophosphate}}{Na_2H_2P_2O_7} + NaHCO_3 \rightarrow \underset{\text{Disodium phosphate}}{2NaHPO_4} + 2CO_2 + H_2O$$

$$Na_2H_2P_2O_7 + NaHCO_3 \rightarrow \underset{\text{Normal sodium pyrophosphate}}{Na_4P_2O_7} + 2CO_2 + H_2O$$

The principal disadvantage of sodium acid pyrophosphate powders is that they require exact control in use because even a slight excess of the residual product, normal sodium pyrophosphate, imparts an objectionable bitter or metallic after-taste to the doughnut or cake in which it is used.

The so-called combination powders contain two acid-reacting constituents, one of which reacts with soda at low temperatures, while the other requires oven temperatures before completing interaction with the soda. This property of supplying carbon dioxide at two temperature levels is generally designated as "double action." A representative example of such a double action powder is the S.A.S.-phosphate type, in which the two acid constituents are sodium aluminum sulfate (S.A.S.) ($Na_2SO_4 \cdot Al_2(SO_4)_3$) and monocalcium phosphate.

In addition to the above categories of baking powders there are others which are more difficult to classify because they contain more than two acid ingredients. Thus one widely used baking powder contains the following constituents: sodium phosphate, monocalcium phosphate, calcium lactate, bicarbonate of soda, and starch, all blended in balanced proportions to yield a minimum of gas evolution during dough or batter mixing, but a uniform, regulated, steady release of the gas in the oven (*171*).

In addition to baking powders of the conventional type, ammonium carbonate and ammonium bicarbonate have found use as chemical leaveners, particularly in the making of cookies and crackers. Both ammonium carbonate and ammonium bicarbonate decompose under the influence of heat into ammonia, carbon dioxide, and water, and hence leave no solid residue. The reaction, in the case of ammonium bicarbonate, may be represented by the following equation:

$$2NH_4HCO_3 + \text{heat} \rightarrow 2NH_3 + 2CO_2 + 2H_2O$$

Because of its greater stability under normal storage conditions, ammonium bicarbonate is the more suitable of the two for bakery use (*164*).

EGGS

The general physical characteristics and chemical composition of eggs are discussed in some detail in a separate chapter on Eggs and Egg Products (Chapter XIII). At this point the functional role only of eggs as related to cake baking will be briefly reviewed.

Eggs not only constitute one of the basic ingredients of cake making, but very frequently are also the most costly single item in a cake batter. They represent at least 30 percent of the total batter cost, and in some types of cakes may approximate one-half the total cost of the ingredients (*172*). Their importance to cake quality becomes apparent from a consideration of their functions as outlined below, which at the same time should serve to underline the need for bakers to give closer attention to the quality of the eggs used, on the one hand, and to the quantity incorporated in cake batters, on the other. Only through the use of liberal amounts of fresh, high quality eggs can the cake baker expect to attain the ultimate improving effect inherent in them.

The functions performed by eggs in cakes may be summarized as follows:

1. **Binding Action:** Eggs contain a considerable proportion of proteins, the egg white solids being practically pure protein, while the egg yolk solids consist of about one-third protein. A characteristic of egg proteins is that they can be readily whipped into an aerated foam, the proteins being denatured in the process and forming a relatively stable

skeleton capable of acting as a framework for the support of other ingredients. In a cake batter, the egg proteins are extended into a complex network in the course of batter mixing in association with the flour gluten to which they thus supply some structural support. Their principal function, however, is not so much one of structure formation as it is one of stabilization. On heating during the oven process, the egg protein network permeating the batter coagulates, thereby contributing rigidity to the cake crumb and assisting the gluten to hold the volume attained. This action is of primary importance in the case of foam-type cakes, such as Angel Food and Sponge Cake, in which the relatively low percentage of flour, with its weak gluten, would normally be inadequate to yield a satisfactory cake volume in the oven.

2. **Leavening Action:** As pointed out above, egg proteins may readily be whipped into a foam-like mass consisting of extremely fine air cells, each surrounded by a film of egg substance. While this property is largely responsible for the stabilizing function of eggs, it also accounts for another significant role played by eggs in cake production. For if such an egg foam is subjected to heat, the air trapped within the foam will expand, thereby increasing the volume of the foam, while the foam itself will become rigid through coagulation of the egg white and will maintain its increased volume. The same action is obtained when the eggs are incorporated into a cake batter. Hence for foam type cakes the whipping properties of eggs are of the greatest importance in determining the product's final volume, cell structure and tenderness. In the case of the heavier batter-type cakes, in which the whipping of eggs is not a factor, eggs also exert a beneficial effect in that (1) their protein films, distributed throughout the batter, provide for an improved retention of the gas generated by the baking powder, and (2) they contribute to uniformity of cell structure by preventing the formation of large air cells through coalescence of minute cells, the protein films of the eggs acting as a stabilizing agent.

3. **Emulsifying Action:** The protein of egg white, when used alone for their binding action, exerts a marked toughening effect on cake crumb, unless other ingredients which act as tenderizers are also used. The egg yolk present in whole egg exerts such a tenderizing function which accounts for the fact that whole egg contributes mellowness rather than toughness to cakes. The constituent of egg yolk which acts as a tenderizer is fat which is present in rather high proportions in yolk. Yolk also contains lecithin which is an effective emulsifying agent.

4. **Flavor:** Egg possesses a mild, but distinctive flavor. If used in relatively large proportions this flavor is imparted to the cake. The need

for care in selecting eggs of fresh flavor is obvious, whether the eggs used are shell eggs or frozen eggs.

5. **Color:** The color contributed by eggs to cake is of considerable importance. Certainly, in the case of Angel Food and White Cake, in which the crumb should be a pure, brilliant white, any off-color would detract materially from the eye appeal of the product. Off-colored egg whites must be guarded against in the production of these types of cake. In Sponge and Yellow Cakes, a rich clear yellow color is aimed at which is determined almost entirely by the color of the egg yolk. For this purpose, yolks possessing a deep color are better suited than are yolk of a light yellow color.

6. **Food Value:** The nutritive value of eggs has long been recognized. Nature has concentrated in them the proteins, fats, minerals and vitamins essential to growth and the maintenance of general well-being. Products to which eggs are added are correspondingly enriched in their nutritive value.

ICINGS

Icings may be defined as "glazings or coatings of sugar and various other ingredients blended together and pleasingly flavored to suit individual tastes" (*173*). They consist of greater or lesser proportions of sugar, fat, milk or milk solids, water, eggs, stabilizers, flavors, salt and colors.

Sugar, which is quantitatively the most important ingredient, can be used in any one of several forms in icings. While granulated sugar will be found both satisfactory and most economical for boiled icings, cold process flat icings require powdered sugars if they are to be free from grittiness or graininess. Confectioners' or 4X sugar will be found suitable for most requirements. If superior smoothness is desired, either a more finely ground powdered sugar, such as 6X or 10X, or fondant sugar of extreme smoothness, may be used. The fondant consists of a sugar mixture made up of approximately 80-85 parts of granulated sugar, 10-15 parts of corn sugar, 5 parts of invert sugar, and 20-25 parts of water, which is boiled to a temperature of 230-232° F. and, on cooling to about 100° F. is then worked to form a plastic mass. Since the product is biologically stable, it can be stored for long periods under suitable conditions.

The shortening or fat content of icings differs markedly with the type of icing: butter cream icings may contain 20 to 25 percent shortening; plain cream icings, 10 to 15 percent; water-type icings, 2.5 to 5 percent. The butter used for icings should possess a mild bland flavor. Its

salt content must be taken into account when salt is added to the icing. Cream of a high butter fat content is also used in the production of superior icings. Chocolate, possessing a high fat content, may also be considered as contributing importantly to the fat content of icings to which it also adds color and flavor. When hydrogenated shortening is used as the principal fat, the addition of small proportions of coconut fat or cacao butter (both of which have high melting points) will improve its setting properties.

Although milk may be used in any one of its various forms, nonfat dry milk solids are generally recommended because they supply flavor and color without adding extra water. In icings which can carry the extra moisture, the use of sweetened condensed milk will markedly enhance the product's flavor. Fresh milk is rarely employed in icings because of its tendency to become sour (*174*).

The major function of water in icings is to serve as a solvent for the sugar. This is true both in the case of flat icings made by the cold process and in boiled icings. In the latter type icings the water dissolves the sugar and permits it to pass through its various physical states without being scorched or discolored by the heat. Most of the water added is driven off during the boiling process so that the final product has a relatively low moisture content. The practice of using water to reduce the consistency of icings frequently leads to a breakdown of the cream, with the fat assuming a curdled appearance. This is caused by part of the sugar, which forms the cream structure, being removed by solution. To thin out icings it is therefore preferable to use simple syrup, such as is obtained by dissolving two parts of sugar in 1 part of water, since this will not cause additional sugar to dissolve at ordinary temperatures. In the case of flat icings, merely warming the icing to a temperature of 100° to 110° F. will decrease its consistency.

Either whole eggs, yolks or whites may be used in the preparation of icings. Fresh whites should be fairly firm in body so that they will whip into a foam of good volume and strength. This will reduce the tendency of the icings to bleed or water out.

The stabilizers used in icing preparation may be any one of a number of various substances capable of taking up and holding an excess of water by forming a gel or possessing the ability to prevent sugar crystallization. Among commonly used stabilizers are included specially processed wheat and corn starches, tapioca, agar, various vegetable gums, gelatin, and pectin.

Agar represents the dried mucilaginous substance extracted from a marine seaweed or algae belonging to the species *Gelidium algae* and growing along the Asiatic sea coast. Hence most of the agar of com-

merce comes from China, Japan, Ceylon and neighboring coasts. While it is insoluble in cold water, it swells considerably, absorbing up to 20 times its own weight of water. It is readily soluble in hot water and is able to set up a firm gel in concentrations as low as 0.5 percent (*175*).

Agar is frequently confused with carragheen or Irish moss, a mucilaginous substance obtained from the seaweed *Chondrus crispus* which grows abundantly along the rocky coasts of northern Europe and North America. This produces a gel which is similar to agar.

Similarly, algin and some of its salts, such as sodium alginate, find some use as stabilizers. Algin is a protein of marine algae obtained as a by-product in the preparation of iodine from kelps.

Among the more important vegetable gums used as icing stabilizers are gum arabic, gum karaya, and locust bean gum. Gum arabic is the exudate of the acacia tree. It is completely soluble in water and possesses a pronounced thickening power. Gum karaya is an Indian gum, obtained as an exudate of *Anogeissus latifolia,* a tree of India. It is also completely soluble in water. Locust bean or carob bean gum is obtained from the bean of the same name. Its preparation involves the separation of the seeds from their shells, the roasting of the endosperm material, the soaking of the roasted material in boiling water to make it swell, and the filtration, drying and grinding of the resulting viscous material. The gum swells in cold water to give a highly stable gel.

Gelatin is obtained from collagen-containing animal tissues (bones, ligaments and skin) by boiling with water under pressure. In its commercial form it is a white powder which dissolves in hot water and sets as the solution cools to form a translucent gel that is tasteless and odorless. It resembles the vegetable gums in many of its properties, although it is a protein whereas the former materials are high polymeric polysaccharides.

Pectin is the name applied to a group of compounds, formed from the protopectin of unripe fruits, which have the property of causing the jellying of fruit juices. Commercial pectin is produced from citrus fruits and apple waste materials by boiling and extracting the juices which are then clarified and evaporated into either a concentrated solution or a dry powder.

These stabilizing agents are used in icings for the purpose of minimizing the development of stickiness under adverse temperature and humidity conditions, imparting and maintaining a softer texture in the icing, and preventing the rapid drying out of the product. The effects of specific types of stabilizers on the sticky characteristics of icings has recently been studied in some detail by Glabau (*176*).

Flavors in icings may be natural, processed or added flavors. Natural

flavors are those which are derived from the normal ingredients, such as butter, milk solids, eggs, etc. Their function is chiefly to underline and supplement the two other types of flavor. Processed flavors are produced in the course of icing preparation by the chemical interaction between various ingredients induced by heat. Thus, by heating a mixture of milk and brown sugar the flavor of caramel is formed, while replacing milk with butter results in a butterscotch flavor under the same conditions. Among added flavors are included the flavor extracts as well as the highly flavored ingredients, such as cocoa, chocolate, fruits and berries which are added chiefly for their flavoring rather than any other properties. The art of correct flavoring is of particular importance in icings since their flavor greatly influences the general appeal exerted by the cake. An improperly flavored icing may impair the palatability of an otherwise acceptable cake, and, conversely, a delicately flavored icing will enhance the quality of an otherwise flavorless baked product.

Salt is an important ingredient of icings, its principal function being to bring out and underline the effect of flavoring ingredients. Icings from which salt has been inadvertently omitted are marked by a flatness of taste and lack in character.

Icings, in spite of their numerous variations, can be classified into three general groups:

(a) Flat icings, i.e., those which have not been subjected to a creaming or whipping process.

(b) Fluffy or creamed icings, such as the various creams and meringues.

(c) Combinations of these two types.

Flat icings are made by mixing sugars and water, with or without the use of additional ingredients. While they may be worked in special mixers, as in the case of fondant icings, they contain little or no incorporated air. They may be prepared either by the so-called cold process, in which all ingredients are used at normal room temperature, or by the hot process, in which hot water is used. Plain water icings are generally modified in their properties by the addition of certain ingredients. Thus small percentages of starch, when heated in a syrup, will increase both the opaqueness and moisture retention of the finished icing by being gelatinized. The addition of small amounts of shortening will increase both the opaqueness and gloss of water icings. Egg white or gelatin impart greater body and improved setting properties, while brittleness in icings may be minimized by the use of small proportions of invert sugar.

Fluffy or creamed type icings may be produced either with shortening or with egg whites. Creams are produced by creaming fats, such as butter or shortening, with powdered sugar. Whole eggs, egg yolks or egg

whites are frequently used as additional ingredients to impart body and smoothness, as well as improved stability, to the icing. Fluffy or foam type icings make use of egg whites which are whipped into a foam and then combined either with icing sugar for cold process icings, or with hot syrups for boiled icings.

CHAPTER XXIII

FLAVOR

PHYSIOLOGY OF ODOR AND TASTE

Food is consumed for the purpose of alleviating or forestalling the sensation of hunger induced by an empty stomach. The kind of food consumed, however, is largely determined by the organoleptic properties of the food. These organoleptic properties include all the chemical and physical characteristics of the food capable of producing olfactory (smell), gustatory (taste) and tactual (touch) sense impressions in the individual. Depending on whether these sense impressions are pleasant or unpleasant, more or less of the particular food is consumed, provided, of course, that the consumer can exercise a free choice.

The impression created by a food upon the gustatory, olfactory and tactual organs of an individual frequently exerts a decisive influence upon the value and degree of utilization which can be derived from the food. The senses of smell, taste and touch may vary markedly in sensitivity in different individuals, and in the same individual at different times. Thus the acuteness of the sense of smell is greatly reduced in a person suffering with the common cold. The sense of taste may have become numbed by abuse with strongly flavored foods. Just as these sense organs may be dulled through misuse, they can also be more fully developed by proper training. It is, therefore, not surprising to have different tasters register different reactions to the same food or beverage, supporting the wisdom of the old proverb, "de gustibus non est disputandum"—there is no disputing about tastes.

In order to understand more fully the taste and olfactory impressions created by food it is necessary to first obtain a clear idea of the physiology of the two organs involved. Detailed descriptions of the olfactory and gustatory organs may be found in most textbooks on physiology or elementary psychology. An abridged but highly adequate description is contained in the book entitled "Flavor" by Crocker (*177*). In the following paragraphs only the briefest outline of the senses involved in organoleptic perception will be presented.

The sensory impressions gained when food is consumed depend importantly on the stimulation of the sense of smell in addition to that of the sense of taste. This participation of the olfactory organ in tasting can

be easily demonstrated by holding one's nose when tasting food. In such cases we detect only the true tastes of the food, namely its sweet, sour, bitter or saline qualities, these four constituting the basic components of taste. Raw onion, under conditions where the olfactory sense is eliminated, has a sweet taste, while apple tastes sweet and sour. The average consumer seldom becomes aware of the extensive contribution made by the olfactory organ to flavor perception and unwittingly transfers smell impressions to the regions where taste perceptions originate.

All sensations, including the olfactory and gustatory perceptions, originate from external stimuli upon peripheral end organs or receptors, the stimuli being conducted over nerve fibers to the cerebral cortex or brain center where the sense impressions are analyzed and interpreted. The receptors of the olfactory organ are located in the upper nasal passages where they are concentrated in a small area of the nasal membrane called the olfactory epithelium. In the case of the gustatory organ the receptors are more widely distributed, being located on the tongue, in the soft palate and in the back portions of the epiglottis. Taste buds show a specificity as to the taste sensation they can detect and it is possible to determine the topographical distribution of the four fundamental taste sensations over the tongue. Thus taste buds responding to sour stimuli are distributed along the sides of the tongue, those responding to salt and sweet stimuli predominate at the tip, while those responding to bitter are localized to the base of the tongue. Carlson and Johnson (*178*) cite evidence obtained from more direct experiments which supports this conception of specific varieties of taste buds, each able to give rise to only one kind of sensation. Thus it was found that certain chemicals (such as sodium sulfate) will produce a sweet taste when applied to one region and a bitter taste when applied to another. In other words, the "sweet" receptors can give rise only to sweet sensation, and the "bitter" receptors only to bitter sensation, no matter what the nature of the stimulating agent.

The olfactory receptors are much more easily fatigued than are the taste receptors. This means that the intensity of any odor, as experienced subjectively, falls off rapidly in only a few minutes of olfactory stimulation. Thus everyone has undoubtedly observed how the odors in a room, which were quite noticeable on entering, seem to rapidly fade away after a stay of a few minutes in the room. A baker working in a shop filled with the odors of baking bread or cake is generally quite unaware of the aromatic quality of his environment which seems so enticing to the passerby or plant visitor.

The simultaneous stimulation of both the olfactory and gustatory senses when food or beverage is consumed results from the fact that the

peripheral end organs of both senses are interconnected by the respiratory air. Substances which act both as olfactory and gustatory stimulating agents are able to reach both peripheral systems by means of the air path connecting the nose and mouth at the back of the mouth cavity. It makes actually little difference whether this process takes place during inhalation or exhalation. The olfactory organ may be reached from two sides, namely, the outside via the nostrils and the interior via the throat. The aromatic substances of food taken into the mouth are volatilized by body heat and are carried to the olfactory epithelium by the exhaled air. The integrated functioning of the gustatory and olfactory senses thus depends largely upon the interconnection established between their receptors by respiratory air. Strictly speaking, the term flavor implies the simultaneous perception of both taste and odor. Thus substances lacking all degree of volatility, such as mineral salts, are said to possess taste but not flavor, while substances perceived only by means of the nose are said to be odorous rather than flavorful. The actual taste is also frequently confused with other properties of food substances. Texture and consistency have a strongly modifying effect on "taste." Thus a crisp cracker does not perceptibly differ in taste from a soggy one, although the overall sense impressions created by the two differ markedly. Actually, the difference lies only in their consistency which results in their different feel against the tongue, teeth, and other parts of the mouth cavity. Temperature also has a marked effect on the sense impression created by the same food or beverage. Hot and cold coffee, being chemically alike, stimulate the taste receptors in the same way. The difference in what is generally called taste between the two is actually a difference in stimulation of the temperature receptors in the mouth.

There is general agreement on the fact that there are only four fundamental tastes—salt, sweet, bitter, sour. A whole series of taste blends are, of course, possible by various combinations of the fundamental tastes. Blends occur most readily with salt and sour, and sweet and sour; less readily with bitter and sweet; and only difficultly or not at all with bitter and salt and bitter and sour. The taste quality that is perceived first also disappears first. The saline quality is tasted before the sweet, the sweet before the sour, and the sour before the bitter.

Whereas it is a relatively simple matter to classify taste sensations into a limited number of categories, the problem with regard to odor classification is beset by considerable difficulties. The tendency of early efforts to classify odors was to set up a large number of classes of odors with numerous subclasses which would cover all conceivable types of odors. Thus Zwaardemaker (*179*) grouped odors under nine classes, several of which contained from three to five subclasses. A typical system of odor

classification which lists six groups of odors, together with their common sources, is the following proposed by Aumueller (*180*):

1. Flowery: Rose, violet, honey.
2. Fruity: Orange, lemon, pineapple, peach, grape, canteloupe, apple, olive oil, vinegar, cider, strawberry, raspberry.
3. Spicy: Cinnamon, cloves, nutmeg, sage, caraway, chocolate, tea, vanilla, wintergreen, peppermint, sarsaparilla.
4. Resinous: Balsam, pine, menthol.
5. Burnt: Coffee, maple, smoked meats.
6. Putrid: Onion, garlic, sauerkraut, fish, lard.

Henning (*181*) attempted to analyze the sensations produced by all odors into a limited number of fundamental sensations instead of classifying odors per se. He reached the conclusion that there are six fundamental odor sensations and that all odors are combinations of one or more of these. His fundamental odor sensations are: spicy, flowery, fruity, resinous, foul, and burnt. Crocker and Henderson (*182*) reduced Henning's six fundamental odor sensations to the following four fundamental sensations:

1. Fragrant, or sweet;
2. Acid or sour;
3. Burnt or empyreumatic;
4. Caprylic, goaty, or oenanthic.

A system for expresing odors numerically has been devised by assigning quantitative values ranging from 0 to 8 for the strengths of the four components. Certain chemical compounds are arbitrarily selected as standards for comparison. This system is claimed to make it possible to represent any odor by a four-digit number. Crocker (*177*), for instance, cites the number 3803 as representing the odor of acetic acid, explaining that the first digit, 3, describes this odor as moderately *fragrant,* 3 on the scale of a possible 8; that the *acid* value is the full 8, which means it is as sour as any known odor; that the *burnt* value is assigned 0, and that the *caprylic* value corresponds to 3.

The additive flavoring materials used in baking may be differentiated into two broad groups, namely spices and seasonings on the one hand, and flavor extracts and essential oils on the other. Spices are aromatic vegetable products, usually marketed in a finely ground state, used for seasoning foods. Flavor extracts are solutions in ethyl alcohol of the flavor principles derived from aromatic plants, while essential oils are the extracted volatile aromatic substances of an oily character obtained from vegetable sources.

SPICES

The spices most commonly used for bakery products include the following:

Cinnamon	Poppy Seed
Mace	Coriander
Caraway	Ginger
Anise	Cloves
Nutmeg	Fennel
Allspice	

In addition to these spices, the use of others has often been suggested, particularly for specialty products. Thus Hall (*183*) points to the use of white pepper in Europe in the well-known Christmas cookies called pepper-nuts. He further suggests that caraway and bay leaves are two spices that might be used to advantage in cookies, pastries, cakes and currant buns. Marjoram, rosemary, and sweet basil offer interesting possibilities in baking. Saffron produces a brilliant color and has an agreeable flavor. There is little doubt that the judicious use of some of these spices by the baker would greatly enhance the appearance, taste and ultimate saleability of his cake and cookie products by the development of new flavors and new forms possessing special appeal for the consumer.

Spices are frequently classified according to the parts of the plant from which they are derived. Thus nutmeg and allspice are fruits, cloves are dried flower buds, ginger is an underground stem, cinnamon is a bark, while caraway and poppy seed are seeds, to cite a few examples. Another system of classification places the spices according to their principal properties into three major groups. Thus, there are the stimulating condiments, such as mustard, pepper, and tumeric; the aromatic spices, such as cloves, cinnamon, and ginger; and the sweet herbs, such as mint, marjoram and fennel, to mention some representative examples from each group.

In the following paragraphs the principal spices used in baking will be briefly characterized. Readers interested in more detailed discussion of spices are referred to the monograph on this subject by Parry (*184*).

Allspice, also known as Pimento, Jamaica Pimento, and Jamaica Pepper, is defined in the Federal Standards (*185*) as "the dried ripe fruit of Pimento officinalis Lindl. It contains not less than 8 percent of quercitannic acid (calculated from the total oxygen absorbed by the aqueous extract), not more than 25 percent of crude fiber, not more than 6 percent of total ash, nor more than 0.4 percent of ash insoluble in hydrochloric acid." The berries grow on an evergreen tree of the myrtle family which

is native to the West Indies and tropical America, as well as Mexico. The individual berry is dark reddish-brown in color, and has a nearly globular shape varying from $\frac{3}{16}$ to $\frac{1}{4}$ of an inch in diameter. The berries are picked when mature, but still green, and are sun-dried for six to ten days. Allspice has a fragrant, clove-like odor and a clove-like, strongly aromatic, pungent taste. The spice has been given its name because its flavor is said to resemble a combination of cinnamon, nutmeg and cloves. The principal constituent of its essential oil, which is present to the extent of 3 to 4.5 percent, is eugenol, comprising some 60 to 80 percent of the aromatic substances of allspice.

Cinnamon is defined (*185*) as "the dried inner bark of cultivated varieties of Cinnamomum zeylanicum Nees." The cultivated tree from which the bark is obtained is native to Ceylon and the Malabar coast of India. It is a small and bushy evergreen belonging to the laurel family. Cinnamon is available in several types based on point of origin, i.e., whether it is cultivated in Saigon, Batavia, Ceylon, etc. While the Ceylon cinnamon possesses the most delicate aroma, bakers have shown preference for the Saigon cinnamon which has not only a delicate bouquet, but appears to be more stable during the baking process. Whereas high quality cinnamon possesses a pleasing, fragrant odor and a warm, sweet, aromatic taste, the lower grades of this spice are marked by a bitter or astringent off-taste. Cinnamon bark yields 0.5 to 1 percent of essential oil whose principal flavoring constituent is cinnamic aldehyde (55-75 percent), with traces of eugenol, cymene benzoic acid and camphor also being present. Cinnamon is probably the most widely liked spice, its appeal being equally great to the young as to the old, and is used extensively for the flavoring of buns, sweet goods, cakes, pies and other baked products.

Cassia is obtained from a tree which is native to China and which greatly resembles the cinnamon tree. Cinnamon and cassia are frequently confused because of this close relationship and cassia bark is sometimes called China cinnamon or simply cinnamon. China cassia has an agreeable odor, somewhat less fragrant than that of Ceylon cinnamon, and a sweet, aromatic, pungent and astringent taste. Cassia bark with slightly modified characteristics is also obtained in Saigon and Batavia. Its essential oils contain as their principal constituent 75-90 percent cinnamic aldehyde, or somewhat more than does cinnamon, which might account for the more pronounced flavor of cassia. In addition to cassia bark, a spice from the same plant in the form of dried, unripe fruits called cassia buds are available. Although they resemble little cloves in appearance, they have a slight cinnamon-like odor and a sweet, warm, pungent taste similar to cassia bark.

Cloves are defined (*185*) as "the dried flower buds of Caryophyllus aromaticus L. They contain not more than 5 percent of clove stems, not less than 15 percent of volatile ether extract, nor more than 0.5 percent of ash insoluble in hydrochloric acid." The plant from which the spice is obtained is an evergreen tree native to the Dutch East Indies and is now cultivated in many tropical and sub-tropical regions. The spice itself represents the air-dried undeveloped blossoms which are borne in bunches of varying number at the ends of twigs. Harvesting is done by pickers who climb the 20 to 40 foot high trees and gather the bunches of unopened clove buds. The cloves are subsequently removed from the bunches by hand. The dried cloves are from ½ to ¾ of an inch in length and in shape resemble round-headed nails, accounting for the derivation of their name from the French word "clou" meaning nail and the Latin "clavus," also meaning nail. They are generally reddish-brown in color and possess a very strong aromatic odor, and a hot, pungent, aromatic taste. Cloves yield from 14 to 21 percent of volatile oil of which the principal constituent is eugenol, representing some 80 to 95 percent of the total. Cloves are graded according to appearance and impurities present into four grades, Special, No. 1, No. 2 and No. 3, listed in declining order.

Ginger is defined in Federal Standards (*185*) as "The washed and dried, or decorticated and dried, rhizome of Zingiber officinale Roscoe. It contains not less than 42 percent starch, not more than 8 percent of crude fiber, not more than 1 percent of lime (CaO), not less than 12 percent cold-water extract, not more than 7 percent of total ash, not more than 2 percent of ash insoluble in hydrochloric acid, nor less than 2 percent of ash soluble in cold water." Ginger, or root ginger, is the thick under-ground stem or rhizome of a perennial herbaceous plant of the ginger family which is native to tropical Asia and is cultivated in the West Indies, India, Africa, China, Japan and the East Indies. Jamaica ginger is generally considered to be of best quality. The spice, which reaches trade channels either whole, cracked, or finely ground, has an agreeable, aromatic, somewhat pungent odor and an aromatic, pungent, biting taste. It is used to flavor pies, cookies, cakes, and gingerbread.

Nutmeg is defined (*185*) as "the dried seed of Myristica fragrans Houtt, deprived of its testa, with or without a thin coating of lime (CaO). It contains not less than 20 percent of non-volatile ether extract, not more than 10 percent of crude fiber, not more than 5 percent of total ash, nor more than 0.5 percent of ash insoluble in hydrochloric acid." The parent plant of nutmeg is an evergreen tree reaching a height of 40 feet or more and is cultivated in Sumatra, Java, and the British West Indies. The fruit resembles a peach in appearance and when ripe, splits

to reveal the crimson seed covering around a hard shiny brown kernel containing the seed, or nutmeg. Nutmegs vary in size, the largest being about 1¼ inches long and ¾ of an inch wide. They are usually oval in shape although some may be nearly globular. Nutmeg possesses a very characteristic and strongly aromatic odor and an aromatic, warm, slightly bitter taste. Nutmeg yields from 7 to 15 percent of volatile oil in which the principal aromatic constituents are cymene and myristicol. East India nutmegs are generally considered superior, and the Penang nutmegs best; although West Indian nutmegs are also of excellent quality. Nutmegs are available whole or ground, and may be used direct for flavoring or as part of pastry spices.

Mace is a product of the nutmeg tree and constitutes the crimson aril or seed covering of the nutmeg kernel. This seed covering is carefully removed, flattened and dried when it changes in color to a pale yellowish or reddish brown. The spice has a fragrant, nutmeg-like odor and an aromatic, slightly warm taste. It loses its flavor rather rapidly after being ground. Mace is used for flavoring cakes, biscuits and sweet doughs.

Anise is defined (*185*) as "the dried fruit of Pimpinella anisum L. It contains not more than 9 percent of total ash, nor more than 1.5 percent of ash insoluble in hydrochloric acid." Aniseed is obtained from an annual herbaceous plant of the parsley family which is cultivated in temperate, warm and hot climates of Europe, India, Mexico and South America. It has a characteristic, agreeable odor and a pleasant, aromatic taste. Aniseed yields from 2 to 3 percent of essential oil in which the principal constituent is anethole (80-90 percent). The spice is available whole or ground and is used to flavor rolls, cakes, cookies and biscuits.

Caraway is defined (*185*) as "the dried fruit of Carum carvi L. It contains not more than 8 percent of total ash, nor more than 1.5 percent of ash insoluble in hydrochloric acid." Caraway seed is obtained from a herbaceous plant of the parsley family which is native to Europe and is cultivated in most parts of the world. The seed has an agreeable odor and an aromatic, pleasant, warm, somewhat sharp taste. The seed yields from 3 to 7 percent of volatile oil in which the principal constituent is carvone, amounting to some 50 to 60 percent of the total essential oil. It is used extensively for flavoring bread, biscuits and cakes.

Coriander is defined (*185*) as "the dried fruit of Coriandrum sativum L. It contains not more than 7 percent of total ash, nor more than 1.5 percent of ash insoluble in hydrochloric acid." Coriander seed is obtained from an herb of the parsley family which is native to Europe and is cultivated almost throughout the world. The herb gives off a pronounced odor which many consider offensive. The name coriander is derived from the Greek word koris, meaning bedbug, since the ancient

Greeks seemed to notice a resemblance between the odors of the herb and of a bedbug. Needless to say, the seeds are free of any such odor, possessing on the contrary a very fragrant odor and a pleasant aromatic taste. Coriander seed yields from 0.1 to 1 percent essential oil of which linalool is the main constituent. Coriander is available whole or ground and is used for flavoring pastry, cookies, buns and cakes.

Fennel seed is defined (*185*) as "the dried fruit of cultivated varieties of Foeniculum vulgare Hill. It contains not more than 9 percent of total ash nor more than 2 percent of ash insoluble in hydrochloric acid." Fennel seed is obtained from a perennial herb of the parsley family native to Europe and cultivated in many regions throughout the world. Although the whole plant is aromatic, commercial use is made principally of the seed which possesses a pleasant, aromatic odor and taste strongly resembling that of aniseed. Fennel seed yields from 4 to 6 percent essential oil whose main constituent, as in aniseed, is anethol. The spice is available whole or ground and is used for flavoring bread, rolls and pastries.

Poppy seed is obtained from an annual herbaceous plant of the poppy family which is indigenous to Asia and is cultivated in Europe and the United States. The seeds, which are slate-colored—although a white variety also exists—are small, hard and round. They possess a slight, pleasant nut-like odor and an agreeable, decidedly nutty taste. The seeds contain 50 to 60 percent fixed oil instead of essential oil. Poppy seed is not usually ground and is used by bakers for spreading on breads, rolls, cakes and cookies.

Spices, as a rule, are imported into the United States in their natural state, i.e., without previous processing except for possible drying or curing to render them less perishable. At the grinding plant they are then thoroughly cleaned, ground to appropriate fineness, and packaged—frequently in air-tight containers to avoid staling. Since the aromatic constituents of spices are subject to evaporative losses or oxidative deterioration on prolonged exposure to the atmosphere, it is inadvisable to maintain excessive inventories of ground spices. Freshly ground spices will in almost all instances possess flavors of a quality and intensity markedly superior to those of spices held six months or more, even if storage is in closed containers and at cool temperatures. For best results the recommendation is not to carry a supply of spices in excess of three months' requirements.

FLAVORING EXTRACTS

According to FDA standards (*185*) a flavoring extract is "A solution in ethyl alcohol of proper strength of the sapid and odorous principles derived from an aromatic plant, or parts of the plant, with or without its

coloring matter, conforming in name to the plant used in its preparation."

The extract may be obtained by one of three methods. Such extracts as those of vanilla, tonka, and ginger are prepared by macerating the plant and extracting the aromatic substances with ethyl alcohol of suitable concentration. A more extensively employed method involves the separation of the essential oils from the plant material by means of steam distillation, the extract being prepared by dissolving the essential oils in ethyl alcohol of suitable concentration. Obviously, this procedure is applicable only to essential oils which are stable at elevated temperatures. In a third method use is made of presses to obtain the aromatic principles which are then also dissolved in ethyl alcohol of proper concentration. With few exceptions, a flavor extract may not contain any substances other than those derived from the plant from which it takes its name. In cases of exception, as in the preparation of vanilla extract, sucrose, dextrose or glycerin may be added. Any addition which modifies the natural color of the original extract must be clearly revealed on the label.

In addition to extracts as such, flavor materials are available also in the form of emulsions. These differ from extracts in that the oils and other aromatic substances obtained from the plant are emulsified with water and some stabilizing agent, such as a vegetable gum, to yield a form of flavor which is frequently more concentrated than is an extract. For this reason, lesser amounts of the emulsion are usually needed to produce an equivalent flavoring effect of a given volume of extract.

The Food and Drug Administration has published standards for a number of essential oils used for the preparation of flavoring extracts, and for flavoring extracts of almond, anise, celery seed, cinnamon, Ceylon cinnamon, clove, ginger, lemon, nutmeg, orange, peppermint, rose, savory, spearmint, star anise, sweet basil, sweet marjoram, thyme, tonka, vanilla, and wintergreen. Of these, extracts of vanilla, ginger and tonka must be prepared directly from the appropriate plant parts, while extracts of almond, anise, cinnamon, Ceylon cinnamon, clove, nutmeg, rose, star anise, and wintergreen must be made by solution of the appropriate essential oil. The remaining extracts may be made by either method.

Very briefly, the FDA standards for flavor extracts (and their essential oils) used most widely for the flavoring of baked foods require them to conform to the following definitions which, it should be noted, make no reference to grade according to quality.

Almond extract: The flavoring extract prepared from oil of bitter almonds, free from hydrocyanic acid. It contains not less than 1 percent by volume of oil of bitter almonds.

Oil of bitter almonds, commercial: The volatile oil obtained from the seed of the bitter almond (*Amygdalus communis L.*), the apricot (*Prunus armeniaca L.*), or the peach (*Amygdalus persica L.*).

Anise extract: Prepared from oil of anise. It contains not less than 3 percent by volume of oil of anise.

Oil of anise: The volatile oil obtained from aniseed.

Cinnamon extract; cassia extract, cassia cinnamon extract: Prepared from oil of cinnamon, containing not less than 2 percent by volume of oil of cinnamon.

Oil of cinnamon; oil of cassia; oil of cassia cinnamon: The lead-free volatile oil obtained from the leaves or bark of *Cinnamomum cassia* (L.) Blume, containing not less than 80 percent by volume of cinnamic aldehyde.

Ceylon cinnamon extract: Prepared from oil of Ceylon cinnamon. It contains not less than 2 percent by volume of oil of Ceylon cinnamon.

Oil of Ceylon cinnamon: The lead-free volatile oil obtained from the bark of the Ceylon cinnamon (*Cinnamomum zeylanicum* Nees). It contains not less than 65 percent by weight of cinnamic aldehyde and not more than 10 percent by weight of eugenol.

Clove extract: Prepared from oil of cloves, containing not less than 2 percent by volume of oil of cloves.

Oil of cloves: The lead-free volatile oil obtained from cloves.

Ginger extract: Prepared from ginger, containing in each 100 cc. the alcohol-soluble matters from not less than 20 g. of ginger.

Lemon extract: The flavoring extract prepared from oil of lemon, from lemon peel, or both. It contains not less than 5 percent by volume of oil of lemon.

Oil of lemon: The volatile oil expressed, without the aid of heat, from the fresh peel of the lemon (*Citrus limonia* Osbeck), with or without the previous separation of the pulp and peel.

Nutmeg extract: The flavoring extract prepared from oil of nutmeg. It contains not less than 2 percent by volume of oil of nutmeg.

Oil of nutmeg: The volatile oil obtained from nutmegs.

Orange extract: The flavoring extract prepared from oil of orange, from orange peel, or both. It contains not less than 5 percent by volume of oil of orange.

Oil of orange: The volatile oil obtained by expression or alcoholic solution, from the fresh peel of the orange (*Citrus aurantium L.*). It has an optical rotation (25° C.) of not less than +95° in a 100-millimeter tube.

Peppermint extract: The flavoring extract prepared from oil of peppermint, from peppermint, or both. It contains not less than 3 percent by volume of oil of peppermint.

Oil of peppermint: The volume oil obtained from peppermint (*Mentha piperita*). It contains not less than 50 percent by weight of menthol.

Tonka extract: The flavoring extract prepared from tonka bean with or without one or more of the following: sugar, dextrose, glycerin. It contains not less than 0.1 percent by weight of coumarin extracted from the tonka bean, together with a corresponding proportion of the other soluble matters thereof.

Tonka bean: The seed of *Coumarouna odorata* Aublet (*Dipteryx odorata*—[Aublet] Willd.).

Vanilla extract: The flavoring extract prepared from vanilla bean with or without one or more of the following: sugar, dextrose, glycerin. It contains in 100 cc. the soluble matters from not less than 10 grams of the vanilla bean.

Vanilla bean: The dried, cured fruit of *Vanilla fragrans* (Salisb.) Ames (*V. planifolia* Andrews).

Vanilla extract is by far the most widely used flavoring substance. The vanilla bean, from which the extract is obtained, is the cured, full-grown, unripe fruit of the vanilla plant which is a perennial vine of the orchid family. Its fruit is a long bean with a brown pulp imbedding large numbers of small hard seeds. The plant is native to eastern Mexico, where it is now cultivated to yield the best commercial beans. It is also cultivated in the West and East Indies, South America, Java, Tahiti, and other tropical regions. Tahiti beans are generally graded the poorest, while Bourbon beans are judged intermediate in quality. In production, the beans, on reaching maturity and just when turning yellow, are picked, placed in piles, and allowed to ferment. This curing process, which requires alternate sweating and drying, lasts for several weeks during which the beans turn dark brown in color. They are then sun-dried, coated with oil, tied in bundles and packed for shipment. The beans frequently develop a cover of minute crystals of vanillin which was formed during the curing process and represents the chief flavoring principle.

The extract is prepared by cutting the beans into small pieces and then macerating them in dilute alcohol, followed by percolation with alcohol. It is a frequent practice to add sugar or glycerin during this percolation process. While the principal flavoring material of the extract is vanillin, other flavoring substances are also present in small amounts which modify the flavor of vanillin. Vanillin can be synthesized quite inexpensively from eugenol or coniferin and is used as the base for synthetic vanilla flavors or as a supplement to pure vanilla extract. Adulterated extracts frequently contain coumarin, the principal flavoring material of the tonka bean. Coumarin is also produced synthetically from certain coal tar products and is used in its own right as a desirable flavoring

compound, possessing a slight vanilla-like odor and showing considerable stability in an alkaline medium.

Flavor extracts should be stored in closed containers at temperatures ranging from 40° to 50° F. and preferably with the exclusion of light. Otterbacher (*186*) mentions experiments which showed that more than half of the common flavors used by bakers are sensitive to light. When stored in flint glass containers, deterioration was most marked in lemon, orange, raspberry and vanilla extracts, while lime, anise, and peppermint showed off-odors to a lesser extent. If kept in the dark, or in amber glass containers, most flavor extracts will keep without deterioration for some three months or more.

As a rule, much loss of flavor occurs during the baking process because baking temperatures are always far above the vaporization point and frequently above the boiling point of the added flavor material. Distillation accounts for most of the quantitative loss. This may be reduced by distributing the flavor in the fat phase of the batch wherever possible. Elevated temperatures also induce decomposition with accompanying condensations and polymerizations in many organic flavoring components. Thus benzaldehyde, vanillin and other aldehydes oxidize readily and undergo partial polymerization and decomposition into carbon monoxide and tasteless hydrocarbons. Esters break down into a great variety of products, while ketones undergo changes similar to those of aldehydes. Important from the viewpoint of the baker is the fact that the effects of light, air and heat result in decomposition products which are low or poor in flavor. Another significant factor in flavor maintenance is the acid reaction of the medium. Since most natural flavors are developed in acid media, their stability is greatly enhanced by ensuring that the pH of the batter or dough is on the acid side. Alkalinity causes the lower aliphatic aldehydes to resinify, while the aromatic aldehydes are changed into acids and alcohols; esters are saponified to their correspondingly alcohols and acids; and ketones are made to undergo condensation reactions, with the ultimate results again being a loss or deterioration of flavor.

Otterbacher (*186*) has recommended the following system for the standardization of flavoring practices in a baking plant, which can be implemented with the part-time services of one girl and requires only a small amount of cool, dry storage space segregated from the actual manufacturing area. The flavor materials should be kept in full, light-proof, well stoppered containers. A day's requirements may be weighed or measured into small, clean, batch-size containers for use in the mixing room. Square bottles, closely fitted in a corrosion resistant metal crate holding one or two dozen containers, are ideal. The mixer operator merely has to empty the full contents of one container into the batch

without further weighing or measuring. This procedure eliminates the danger of under- or over-flavoring and also avoids exposure of large quantities of flavor material to light, spillage, evaporation and other deleterious influences. The small containers are always cleaned when returned to the flavor center for refilling.

In most cases, the final flavor of a baked product is only partly due to the addition of a specific flavor material. Of equal or greater importance are frequently such factors as nature and quality of raw materials used, the conditions under which the ingredients have been stored, formula balance, fermentation in the case of yeast-raised products, baking conditions, cooling conditions, type of packaging material, and others.

Rather interesting observations concerning the flavoring of cakes have been recorded by Watts and Graham (*187*). They found that cakes could be flavored entirely by absorption in closed containers after baking. In their experiments, small amounts of various flavoring extracts were placed in small containers in the bottom of dessicators and the cakes allowed to remain in the dessicators for stated periods. The results showed that both foam type and batter type cakes quickly absorbed the flavorings (vanilla, almond, etc.), optimum flavoring effects being obtained in from one half to three hours. The cakes could be put in the dessicator either hot or cold. The flavors were in each case clear cut and readily recognizable, whereas when the same flavors were added to the cake batters prior to baking, the resulting cakes were either flavorless, resembling controls without added flavor, or the flavors were altered by the baking. If several flavors were used in a single dessicator, or if cakes flavored differently by this method were stored side by side, the combination of flavors produced an effect described by most judges as "stale" or "flat." These experiments indicate that possibly much more satisfactory results could be obtained by commercial bakers if no attempt were made to add volatile flavorings prior to baking and if the finished cakes were segregated into special cases or closed compartments, each containing a separate flavoring material.

COCOA AND CHOCOLATE

Because cocoa and chocolate are used primarily for the desirable flavor they impart to cake products, they are conveniently considered at this point, although they differ from the usual flavor materials in that they also contribute definite substance, color and food value to the finished product.

The common source of both is the cacao bean,* which is actually a

* The difference in spelling between the term denoting the end product and that referring to the source material should be noted. The name *cocoa* is applied to the finished article of commerce, while *cacao* is used when referring to the bean and when used as a descriptive adjective.

seed of *Theobroma cacao,* or cacao palm tree, cultivated in equatorial Africa, Brazil, and the tropical regions of South America. The fruit of this tree is a pod which may attain 4 inches in diameter and 12 inches in length. Imbedded in its soft white or pinkish pulp are 25 to 75 seeds in 5 rows which constitute the cacao beans of commerce. The ripe pods are removed from the tree and subjected to a fermentation which facilitates the removal of the adhering pulp from the bean proper and at the same time imparts aroma, flavor and color to the bean. On completion of the fermentation the beans are cured to reduce their moisture content from about 33 percent to less than 8 percent to permit their safe storage and shipment. The combined fermentation and drying processes may take anywhere from 6 to 20 days. The dried beans are then shipped to the manufacturer for processing into chocolate and cocoa.

The cacao beans, which consist of a shell constituting about 14 percent of the total, and the inside of the bean, called the nib, making up the remaining 86 percent of the seed, on reaching the processing plant are first thoroughly cleaned by mechanical means. They are then subjected to the highly important roasting process during which the shell of the bean is dried out, thereby facilitating its subsequent removal, and the characteristic chocolate flavor and aroma are developed in the nib or kernel. After the beans have been properly roasted, they are dehusked by passage between properly adjusted rolls which crack the shells, followed by mechanical winnowing. This separation of shells and nibs should be as complete as possible, since the shells contribute neither to the food value nor to the aroma of the final product and may impart a definite off-taste. The roasted nibs next go to the mills where they are reduced into a finely ground homogeneous mass, called chocolate liquor, or also bitter or baking chocolate. During the grinding operation the temperature is increased to over 40° C. and, because the nibs have a fat content of over 50 percent, the ground mass becomes fluid and can be run into molds. It is this molded chocolate that is principally used by bakers for the production of chocolate cakes and cookies. For consumer use, the chocolate liquor receives additional treatment, such as further grinding and refining, with the addition of various flavors, sugar, milk, etc.

The composition of the chocolate liquor produced by the mills is indicated in Table 123 (*188*).

The various chocolate products must conform to the following Federal Standards and definitions:

"*Chocolate, plain chocolate, chocolate liquor, chocolate paste, bitter chocolate liquor:* The solid or plastic mass obtained by grinding cacao nibs. It contains not less than 50 percent cacao fat and, on the fat- and moisture-free basis, not more than 8 percent total ash, not more than 0.4

ash insoluble in hydrochloric acid, nor more than 7 percent crude fiber.

"*Sweet chocolate, sweet chocolate coating:* Chocolate mixed with sugar and/or dextrose, with or without the addition of cacao butter, spices, or other flavoring materials. It contains on the moisture-, sugar-, and fat-free basis, no greater percent of total ash, acid-insoluble ash, or crude fiber, respectively, than is found in moisture- and fat-free chocolate.

"*Milk chocolate, sweet milk chocolate:* The product obtained by grinding chocolate with sugar and/or dextrose, with the solids of whole milk, or the components of milk solids in proportions normal for whole milk, and with or without cacao butter, and/or flavoring materials. It contains not less than 12 percent of milk solids."

Table 123. Composition of Chocolate Liquor

	Percent
Moisture	1.70
Fat	54.00
Theobromine	1.08
Caffeine	0.42
Other nitrogen substances	0.42
Pure starch (by diastase)	8.21
Crude fiber	2.65
Other carbohydrates	17.32
Total ash	3.04
Water-soluble ash	0.72
Water-insoluble ash	2.32
Acid-insoluble ash	0.02

Cocoa results when the chocolate liquor, obtained from the mills, is passed through hydraulic presses where most of the fat, or cacao butter, is expelled. The press cake remaining after the extraction of the cacao butter will have a fat content of 8 to 25 percent, depending upon the duration and degree of pressure applied. The press cake is then ground to a fine powder in micro-pulverizers to yield the powdered cocoa of commerce. Since cacao butter is relatively neutral in flavor, its extraction results in an intensification of flavor in the cocoa which therefore normally contains from 1.5 to 1.7 times as much flavor as chocolate.

Cocoas are differentiated into natural and "Dutched" cocoas. The method of "Dutching" originated in Holland and had for its purpose the darkening of the cocoa's color. The removal of the fat and the fine grinding leaves the cocoa much lighter in color than chocolate. "Dutching" resulted from attempts to darken the powder and affords the cocoa manufacturer a better control over the color of his product. The process also exerts other effects, such as improving the product's solubility in the sense that it will have a lesser tendency to settle out of solution than

natural, untreated cocoa. "Dutching," as usually carried out, involves the use of alkaline substances, such as the carbonates, bicarbonates, and the hydroxides of sodium, potassium and ammonium. In practice, the procedure is to add an aqueous solution of the alkali to the partially roasted beans. Roasting is then continued until the added water has evaporated and the beans have attained the desired color. From that point on they are treated the same as natural cocoa.

Cocoa exhibits considerable hygroscopic properties, due largely to the fact that during the roasting process a major portion of the starch present in the raw nibs is converted into dextrines under the influence of heat. These dextrines show a great affinity for moisture when incorporated into a batter which must be compensated for by a reduction in flour on the order of 10 to 15 percent of the amount of cocoa added.

Cacao products may vary in their pH values from 5.2 to as high as 8.8 for heavily dutched cocoa. The pH of natural cacao products, which include chocolate liquor and cocoa powder, is generally within the range of 5.2 to 6.0. This variation in pH is attributable to the variable amounts of different organic acids and other acid-reacting substances that are present. The pH of dutched cocoas is influenced by the type and amount of alkali used, the normal range being from 6.0 to 8.8. The pH of the cocoa is of importance in determining the amount and type of leavening agent to be used in the cake formula. Natural cocoas, being acid in character, require the use of baking soda. The acidity of the cocoa liberates the carbon dioxide gas from the sodium bicarbonate and thereby aids in aerating the batter. At the same time the acidity is neutralized with an improvement of the cocoa color. The color of the cocoa pigments changes from a cinnamon-brown at pH 5.0 to a true chocolate-brown at pH 7.0 and to a rich mahogany at pH 7.5. Care must be exercised not to increase the alkalinity too much since there is a very marked deterioration of flavor at a pH above 8.0. As the dutching of a cocoa becomes heavier, its soda requirements becomes less, with a corresponding reduction in leavening action. The use of heavily dutched cocoas must be supplemented by appropriate amounts of baking powder to obtain proper leavening action. One recommended rule in this connection is to replace the quantity of sodium bicarbonate withheld from the batter by twice the amount of baking powder (*189*).

The addition of chocolate or cocoa to the batter may be done by one of several procedures. In the case of chocolate it is essential that the material be first carefully melted. Melting should be carried out in jacketed kettles—never over a direct fire—and at moderate temperatures to avoid the development of off-flavors or burnt flavors. In the case of cocoa, the method of incorporation should be adapted to the type of batter being produced. The following procedures are recommended:

1. For pound cakes and batter cakes made by the creaming method, the cocoa should be creamed with the sugar and shortening.

2. For cakes made by the blending method with high absorption shortenings, the cocoa should be blended with the shortening, flour and part of the sugar.

3. For foam type cakes, the cocoa should be blended with the flour and some of the sugar by sifting.

Other methods which have been suggested include mixing the cocoa with sugar and dissolving in hot milk; incorporating in a cocoa stock; and mixing with melted shortening to make a "reconstituted liquor."

Schaal and Montminy (*189*) have classified cocoa and chocolate cakes into four basic types, namely, devil's food cake, fudge cake, chocolate cake, and milk chocolate cake. Representative formulas of these four types are given in the following table, on both the flour basis and the percent basis.

TABLE 124. CLASSIFICATION OF COCOA AND CHOCOLATE CAKES

Ingredients	Devil's Food Cake Lbs.	Fudge Cake Lbs.	Chocolate Cake Lbs.	Milk Chocolate Cake Lbs.
	Flour Weight Basis			
Flour	100	100	100	100
Sugar	170	193	160	160
Shortening	75	65	48	55
Eggs (whole)	90	80	60	60
Cocoa (natural)	48	48	—	—
Chocolate liquor	—	—	48	25
Dry milk solids, nonfat	20	20	17	50
Water	150	152	128	130
Salt	3¾	3¾	3¾	3¾
Soda	3¾	1¼	¾	¾
Baking powder	—	3	3¾	3¾
Batter weight	660½	666	569½	588¼
	Percent Basis			
Flour	15.1	15.0	17.6	17.0
Sugar	25.8	29.0	28.1	27.2
Shortening	11.4	9.8	8.4	9.4
Eggs (whole)	13.6	12.0	10.5	10.2
Cocoa (natural)	7.3	7.2	—	—
Chocolate liquor	—	—	8.4	4.2
Dry milk solids, nonfat	3.0	3.0	3.0	8.4
Water	22.7	22.8	22.5	22.2
Salt	.55	.56	.68	.64
Soda	.55	.19	.16	.12
Baking powder	0	.45	.68	.64
Batter weight	100	100	100	100

It should be pointed out that the U.S. Food and Drug Administration, as well as the corresponding agencies of the majority of states, recognize a difference between chocolate and cocoa so that care is needed in the labeling of products in which either is used as an ingredient. Thus, it is not permissible to call a cake a chocolate cake if cocoa has been used in it and vice versa. Attention is called to this fact because it is quite readily possible to substitute one for the other with appropriate adjustments in the shortening content of the formula, since it is the fat content which is primarily affected by such substitution. The basis of substitution is, of course, the fact that cocoa contains less fat than chocolate liquor, the fat content of cocoa being 20 percent on an average, compared with 50 percent in chocolate. In converting one pound of chocolate liquor containing 8 ozs. of non-fat cacao solids and 8 ozs. of cacao butter into cocoa, 6 ozs. of cacao butter are extracted, leaving a cocoa product containing the original 8 ozs. of non-fat solids and only 2 ozs. of fat. Cacao butter possesses only one-half the shortening value of all-hydrogenated shortening. Hence, in order to convert cocoa into a chocolate substitute, 10 ozs. of cocoa with 3 ozs. of shortening must be used for every pound of chocolate liquor replaced. Another way of stating this rule is: Use cocoa equal to $\frac{5}{8}$ the weight of the chocolate liquor plus shortening equal to $\frac{1}{2}$ the difference between this figure and the chocolate liquor. Conversely, if one is to substitute chocolate liquor for cocoa, the rule is as follows: Multiply the weight of cocoa by $\frac{8}{5}$ to get the weight of chocolate and then omit from the batch an amount of shortening equal to $\frac{1}{2}$ of the increased weight of the chocolate liquor over the original cocoa. Examples of how these rules work out numerically are given in the following table *(190)*:

TABLE 125. TRANSPOSITION VALUES FOR CHOCOLATE AND COCOA

COCOA FOR CHOCOLATE						CHOCOLATE FOR COCOA					
To replace Chocolate		Use Cocoa		Increase Shortening		To replace Cocoa		Use Chocolate		Reduce Shortening	
Lbs.	Ozs.	Lbs.	Ozs.	Lbs.	Ozs.	Lbs.	Ozs.	Lbs.	Ozs.	Lbs.	Ozs.
	4		3		1		4		6		1
	8		5		2		8		13		2
	12		8		2		12	1	3		4
1			10		3	1		1	10		5
2		1	4		6	2		3	3		10
4		2	8		12	4		6	6	1	3
6		3	12	1	2	6		9	9	1	13
8		5	—	1	8	8		12	12	2	6
12		6	4	1	14	10		16	—	3	—

CHAPTER XXIV

CAKE BAKING TECHNOLOGY

BALANCING CAKE FORMULAS

Formula balance refers to the combination of essential cake ingredients in such proportions as to yield a cake of high quality as judged by consumer acceptance. According to Coughlin "The balanced formula has the proper quantities and proportions of essential ingredients for good cake." Since each type of cake exhibits its own particular characteristics, it is obvious that different cakes require different combinations of ingredients. Each ingredient, in turn, exerts an individual effect upon the general characteristics of the final product so that a basic change in one ingredient requires an appropriate adjustment in the proportions of all other ingredients. This mutual interdependence of basic cake ingredients will become more understandable if their main functions in a cake are briefly reviewed. Coughlin (*191*) has enumerated five functions of ingredients:

1. Tougheners
2. Tenderizers
3. Moisteners
4. Dryers
5. Flavorers

Among the toughening ingredients may be included the flour, milk solids, and egg whites; among the tenderizing agents, the sugar, shortening, chocolate, fat in egg yolks; among the moisteners, the fluid milk and eggs; among the dryers, the flour, sugar, dry milks, cocoa; and among the flavorers, the sugar, cocoa, chocolate and practically all other ingredients. To produce a cake of excellent eating quality, it is essential to so proportion the various ingredients from their functional viewpoint that the toughening or binding ingredients are counterbalanced by the tenderizing materials, the drying substances by the moisteners, and vice versa. Only a proper balance of these ingredients will yield a cake that will excel in structure, volume, keeping quality, palatability and flavor.

Perhaps the oldest example of an aerated batter type cake is the old-fashioned pound cake with its four basic ingredients—flour, sugar, butter and eggs—each present in equal amounts. Its name is derived from the

fact that its household formula called for one pound each of these four ingredients.

TABLE 126. OLD-FASHIONED POUND CAKE

Ingredients	Lbs.	Ozs.	Batter Percentage	Percentage based on Flour as 100%
Butter	1	—	25.0	100.0
Flour	1	—	25.0	100.0
Eggs	1	—	25.0	100.0
Sugar	1	—	25.0	100.0

This formula has served as the starting point for a great many cake variations, some of which show only a slight resemblance to the original pound cake. The rather high cost of the original formula has resulted in a limitation of its use to special occasions only and in the introduction of modifications designed to make the production of the cake more adaptable to commercial baking conditions, on the one hand, and to reduce the cost per ounce of batter on the other hand. One of the first aims of formula changes was to improve the cake volume which is notoriously low with the original formula. It was soon found that formulas of any desired degree of richness in terms of fat and eggs could be devised by following three simple rules of formula balance which would ensure against cake failures (though not against loss of cake quality):

1. The weight of the shortening should equal the weight of whole eggs.
2. The weight of the sugar should equal the weight of the flour.
3. The combined weight of eggs and milk should equal the weight of the flour or sugar.

Even a superficial consideration of these rules of formula balance discloses the fact that they permit the construction of pound cake formulas with an extreme range in richness as far as the shortening and eggs are concerned since these two ingredients, though balanced against each other, have no quantitative reference to either of the other ingredients. Hence the lower limit is governed only by the individual baker's concept as to how lean a formula can be made without a serious loss in palatability in the finished cake. Mary Brooke (*192*) on examining six average commercial pound cake formulas, made the following observations: Their sugar content varied from 79 to 120 percent (based on flour), their shortening content from 45 to 68 percent, their egg content from 46 to 68 percent, and their milk from 22.5 to 70 percent. Obviously, this range in variation of the individual ingredients is bound to give rise to a corresponding variability in the characteristics of the final cake products. It

is also equally obvious that lean pound cakes, with their deficiencies in fat and egg contents, will lack the richness traditionally associated with pound cakes and will not contribute to the development of the commercial cake baker's business.

Most modern batter type cakes are based in their formulation on the use of so-called high-emulsifying or superglycerinated shortenings with their high liquid and sugar carrying capacity. Keeping this fact in mind, the rules for balancing modern high-sugar, high-liquid cakes may be generalized as follows:

1. The weight of the sugar should exceed that of the flour.
2. The weight of the eggs should exceed that of the fat.
3. The weight of the liquid in the eggs and milk should equal or exceed slightly the weight of the sugar.

The amount of sugar that can be incorporated in a cake formula varies within rather wide limits. While it is difficult to establish a generally acceptable lower limit, this depending entirely on the individual baker's concept as to what constitutes leanness in a cake, few formulas in which high-emulsifying shortening is used would call for less than 100 percent sugar based on flour. The upper limit is generally given at 150 percent sugar for white and yellow batters, whereas batters containing appreciable amounts of cocoa or chocolate will tolerate still higher sugar ratios, the practical top limit being 180 percent. The actual amount of sugar used will depend upon other factors, such as, for example, the amount of liquids used. Sufficient liquids in the form of milk and eggs must be present to bring the sugar into solution without depriving the flour starch of adequate moisture for gelatinization (*193*). Consequently, the sugar cannot exceed about 90 to 95 percent of the combined liquids. Once the sugar ratio has been selected, the amounts of both the sugar and the flour become fixed. The remaining ingredients must then be adjusted to the quantities of these two materials.

The second rule reads that the weight of the eggs should exceed that of fat. Because of the high protein content of eggs, they exert a toughening effect which must be counteracted by the tenderizing action produced by an appropriate amount of shortening. Whereas with the older formulas, containing regular hydrogenated shortenings, the accepted practice was to use equal amounts of eggs and of shortening, the modern high-emulsifying shortenings possess a somewhat greater tenderizing effect so that, as a general rule, the fat content is kept about 15 percent lower than the egg content. These considerations are based on whole eggs, and if either whites or yolks are used appropriate adjustments must be made. In the case of whites, with their higher moisture and lower protein con-

tents as compared to whole eggs, a downward adjustment of the shortening, or a proportionate increase in the whites, must be made for best results. In instances where yolks primarily are used, their high fat content and low moisture content must be considered in determining the proper fat ratio. In the normal yellow and white cakes, the shortening will range from 35 to 50 percent based on flour. Hence the amount of eggs, being required at least to equal and preferably to exceed the amount of fat, will be beyond that range. Because of the rather high cost of eggs, however, the general practice is to keep their proportion in the formula as close to the actual requirements imposed by the fat content as possible. One of the functions of eggs is that of an emulsifying agent and a shortage of eggs in relation to fat results in poor dispersion of the shortening in the batter, with consequent impairment of the texture and volume of the finished cake. Also, a disproportionately high content of fat tends to yield cakes which give an impression of excessive greasiness.

According to the third rule, the weight of the combined liquids in eggs and milk must equal or exceed slightly the weight of the sugar. Liquids, in the sense used here, refer to the total weight of the liquid ingredients, i.e., eggs and milk, rather than to their actual moisture contents. In cakes made with ordinary shortening, the weight of the milk is usually about equal to the weight of the eggs and their combined weights will about equal that of the flour. On the other hand, in cake made with superglycerinated shortening the amount of milk may be double that of eggs, and their combined weights may be increased to as much as 165 percent based on the flour. This ability to carry an increased amount of liquids is one of the distinguishing characteristics of modern cake flours and of the emulsifying type shortenings. The incorporation of sufficient liquids is essential to good cake quality. If too little liquids are used, the resulting cake will show a harsh texture, combined with dryness of crumb and impaired palatability. Excessive use of liquids will weaken the structure so that the cake may fail to achieve adequate volume or collapse in the oven subsequent to a satisfactory rise.

Representative formulas for different yellow cake varieties are shown in Table 127. The ingredients listed are basic and can be augmented by various optional ingredients such as nuts, fruits, spices, etc. The slight differences in the formulas for layer cakes and loaf cakes take into account the fact that layers require less structural strength than do loaves and may for this reason contain more liquids and sugars.

The ingredients and their proportions in white cakes differ from those of yellow cakes only in minor respects, excepting the eggs. White cakes require the use of egg whites instead of whole eggs or yolks and, as a rule,

TABLE 127. REPRESENTATIVE FORMULAS FOR DIFFERENT VARIETIES OF YELLOW CAKES
(Ingredients expressed as percent of total batter weight)

Ingredients	Ordinary yellow cake[1]	High-ratio loaf cake[2]	High-ratio layer cake[2]
Sugar	25.5	29.6	29.8
Flour	29.8	22.5	21.2
Fat	13.4	11.4	11.6
Whole eggs	14.8	11.4	12.6
Milk	14.8	22.5	22.2
Baking powder	0.7	1.3	1.3
Salt	0.6	0.8	0.8
Flavor	0.4	0.5	0.5
Total	100.0	100.0	100.0

[1] Made with regular hydrogenated shortening
[2] Made with high-emulsifying shortening

some 25 to 35 percent more whites are used than whole eggs. Typical white cake formulas are shown in the following table.

TABLE 128. REPRESENTATIVE FORMULAS FOR DIFFERENT VARIETIES OF WHITE CAKES
(Ingredients expressed as percent of total batter weight)

Ingredients	Ordinary white cake[1]	High-ratio cake[2]
Sugar	25.8	29.3
Flour	25.8	20.9
Fat	13.0	11.5
Egg whites	17.8	15.7
Milk	15.4	20.0
Baking powder	0.9	1.3
Salt	0.6	0.8
Flavor	0.5	0.5
Total	100.0	100.0

[1] Made with regular hydrogenated shortening
[2] Made with high-emulsifying shortening

The formula balance rules outlined above have been established by exacting research studies under close scientific control and, although they allow sufficient leeway to permit adaptation to specific conditions, they should be applied with a minimum of deviation if cakes of superior character, palatability and keeping quality are to result. Davies (*194*), in a study of the effects of variations in ingredient ratios, has obtained the following results: Using a properly balanced cake formula as the control, increasing the sugar by 25 percent resulted in a coarser, less uniform

grain, a slight increase in cake volume and a more tender texture, while decreasing the sugar by 25 percent gave a finer grain than the control, a smaller volume and a slightly tough and tight texture; an upward change in fat of 25 percent resulted in no noticeable change in the grain of the finished cake, a slight decrease in its volume and a somewhat greasy feel in the texture, while a decrease in fat of the same order below the control level gave the same or slightly coarser grain as in the control cake, a larger volume, and a tight harsh texture; an increase in liquids of 25 percent brought about a finer grain, a smaller volume and a moist and tender texture, whereas a corresponding decrease in liquid produced a coarse and less uniform grain, a larger volume, and a harsh dry texture. When baking powder was increased by 50 percent, a somewhat coarse but uniform grain, larger volume and slightly harsh texture resulted, while a 50 percent decrease in baking powder produced a cake which possessed a fine, close grain, a smaller volume, and a tight and slightly soggy texture.

While the high-sugar content batter-type cakes are enjoying increasing popularity, there is still a demand for the older type, low-sugar content cakes. The general rules applying to the production of these cakes are as follows:

1. The weight of sugar should be less than that of the flour.
2. The weight of the eggs should exceed that of the fat.
3. The combined weights of liquid ingredients should equal the weight of the flour.

It will be noted that rules 2 and 3 are identical in the case of both high-sugar and low-sugar content cakes. Hence, the proportion of sugar in relation to flour largely determines the type of cake. However, there are actually additional adjustments in the proportions of liquids and shortening, the latter being of the regular hydrogenated type rather than a superglycerinated fat. The practical differences in ingredient proportions may be noted from the formulas shown in the above two tables.

The discussion has thus far centered upon the balancing of the more complex batter-type cakes. Foam-type cakes, such as angel food and sponge cakes, also require the proper proportioning of their ingredients. The general rules applying to angel food cake may be summarized as follows:

1. The weight of the sugar should equal the weight of the egg whites.
2. The weight of the flour should approximate one-third the weight of either the sugar or the egg whites.

Thus, angel food cake is based essentially on the relatively simple formula of 1 part of flour to each 3 parts of egg whites and 3 parts of sugar.

Sponge cakes differ from angel food cakes mainly in that they use whole eggs instead of just egg whites. In balancing their formulas the principal aim is to reduce the toughening effect of the whole eggs by incorporating a sufficient amount of sugar with an appropriate amount of liquids. The general rules may be stated as follows:

1. The amount of sugar should equal or slightly exceed the amount of whole eggs.
2. The combined weights of the liquid in whole eggs and milk or water should exceed the weight of the sugar.
3. The weight of the sugar or the whole eggs should exceed that of the flour.
4. The combined weights of the eggs and flour should exceed the combined weights of the sugar and liquids other than whole eggs (milk or water).

HIGH ALTITUDE FORMULA ADJUSTMENTS

Unless specifically indicated otherwise, cake formulas released to commercial bakers are developed for use at altitudes approaching sea level. Early experiences have shown that formulas for batter type cakes which yield satisfactory results at low altitudes failed to perform equally well at high altitudes unless certain quantitative adjustments in ingredients were made to compensate for the effects of reduced atmospheric pressure. The ingredients involved include the flour, eggs, and baking powder.

Flour must be increased with increasing elevation. This upward adjustment in flour does not become necessary until an elevation of about 3000 ft. is reached. At 3500 ft. elevation, the flour should be increased by 2.5 percent, and as elevation increases, a corresponding increase in flour must be made up to 10 percent at 8000 ft. elevation.

The egg content, whether consisting of whole eggs or egg whites, must be increased with increasing elevation. The first formula adjustment with regards to eggs is usually required at an elevation of 2500 ft. at which level the egg content should be increased by 2.5 percent. Again, with increasing elevation the egg content must be increased correspondingly until 15 percent additional eggs must be used at an elevation of 7500 ft. By increasing the egg content, the liquid content of the formula is increased proportionately, thereby balancing the extra flour needed at the higher altitudes, and at the same time providing greater stability through the strengthening action of the egg protein.

The baking powder, or other materials used for leavening purposes, must be reduced with increasing elevation. The initial adjustment in the form of a 15 percent reduction becomes necessary at an elevation of only 2000 ft. and increasingly larger proportions of the leavening material must be withheld from the formula as the altitude increases until at an elevation of 8000 ft. the reduction amounts to 60 percent. The relation-

ship of altitude to the amount of the three ingredients is shown in the following chart (*190*).

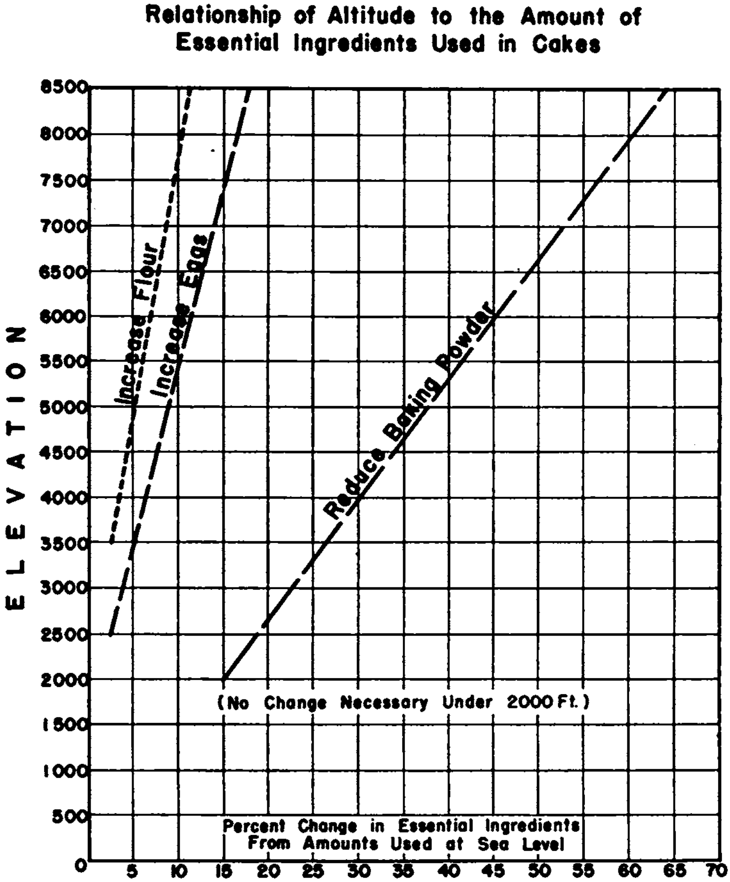


FIG. 110—Effect of altitude on cake batter formulation. (*Courtesy General Mills, Inc.*)

These corrections are applicable only to high-sugar content cakes in which superglycerinated fat is used as the shortening. In the case of low-sugar content cakes using ordinary shortening, formula adjustments to increasing altitudes consist of reducing the baking powder and sugar and increasing the liquid. These changes will safeguard the general physical appearance of the cake, but will detract from its palatability as a result of an insufficient sugar content.

Additional factors which have an effect on successful cake baking at high altitudes (above 4500 ft.) include the following: (1) Baking pans should be more thoroughly and heavily greased to prevent cakes from

sticking to the sides and bottom of the pans. The use of silicone type pan coatings will minimize the problem of sticking. (2) Adjustments in egg content should be made using either egg whites or whole eggs, rather than egg yolks, as the yolks contain insufficient moisture to satisfy the need for increased liquid. (3) Egg whites and whole eggs require less beating for foam type cakes. The cream of tartar should be reduced in the same proportion as the baking powder. (4) The oven temperature should be increased by 25° F. over that recommended for baking at sea level, with no change in baking time. Because of the increased rate of evaporation at higher altitudes, care must be taken to prevent overbaking with its pronounced drying-out effect. (5) Cakes should be removed from the baking pans immediately on emerging from the oven and cooled in an area protected against strong air currents in order to have them retain a maximum of moisture and freshness. They also should be iced as soon as they are properly cooled.

CAKE MIXING METHODS

The primary purpose of cake mixing is to bring about a homogeneous dispersion of the several cake ingredients, usually with a maximum incorporation of air and a minimum development of the gluten in the flour. Depending upon the type of cake being produced, the procedure will differ with respect to the order of ingredient addition, the time and speed of mixing at the various stages in multi-stage methods, the temperature of the ingredients being used, and other factors. No attempt can be made here to indicate all of the various modifications in basic cake mixing methods that have been suggested by different writers. In the following paragraphs are outlined the more important practical procedures that are currently being used by commercial bakers in the production of fat containing cakes.

The ingredients of batter type cakes may be combined by any one of three basically different procedures. They are generally designated as the "sugar batter" or creaming method, the "flour-batter" or blending method, and the "single stage" method. In the creaming procedure, the shortening and the sugar are first creamed together at medium speed, then the eggs are added with creaming continued, and the mixing is completed by adding the milk and the flour, in alternate small portions. Among the advantages of this method are a maximum incorporation of air in the fat-phase of the batter, and a minimum development of flour gluten. In the case of modern high-quality cake flours the latter point no longer possesses the significance it formerly had. The total mixing time ranges from 15 to 20 minutes, with the initial creaming stage requiring 8 to 10 minutes, the second stage of egg incorporation requiring

an additional 5 minutes, and the final stage of milk and flour addition taking 5 to 6 minutes. This method is suitable for all regular batter type cakes, but not for high sugar content cakes. Bailey and LeClerc (*172*) point out that during the mixing process the water in the milk and eggs produces an emulsion with the shortening. By adding the eggs and milk gradually a water-in-fat dispersion results. Care must be exercised in adding the eggs and milk slowly, otherwise the phase of the emulsion may change from a water-in-fat to a fat-in-water dispersion which imparts a curdled mass appearance to the batter. The batter may, however, be smoothed out again by the addition of the flour without any perceptible impairment of the quality in the finished cake.

In the flour-batter method, the shortening and flour are creamed together until a fluffy mass is obtained, and the eggs and sugar are whipped together at second speed until a semi-firm foam results. Both these steps, which should be carried out simultaneously in two different bowls, require about 10 minutes. The sugar-egg foam is next combined with the creamed flour and shortening, after which the milk is added in small portions. The main advantage of this method is the very effective dispersion and distribution of the shortening throughout the batter. The result is a cake of extremely fine grain and texture which in turn permits the use of higher proportions of sugar and liquids than the sugar batter. Among the method's disadvantages are a somewhat lower volume of air incorporation in the batter, a more pronounced development of the gluten in the flour with its accompanying toughening of the cake, and the requirement of two bowls instead of one.

The single-stage method consists of placing all the major ingredients into the bowl at one time and mixing. The baking powder is usually added toward the end of the mixing period. In the conventional single-stage method, the first blending of the ingredients is done with a flat beater for 1 to 2 minutes at low speed, followed by mixing at second speed for 3 to 5 minutes, and completed for 2 minutes at low speed, for a total mixing time of 8 to 10 minutes.

A modification of the single-stage method consists of placing all the ingredients, except the eggs, into the mixing bowl and beating with the wire whip for about 1 minute at high speed. The eggs are then added and stirred in on low speed for about one half minute. The total mixing time of this streamlined method is thus only 1½ minutes. It has the obvious advantage of speed and is said to eliminate some of the variables due to different creaming times or batter temperatures.

There are a number of additional mixing method variations, all of which are claimed to yield good results. Thus, in a method recently advocated by Carrie (*195*) all sugar required by the formula is placed in a

mixing bowl together with about one-half its weight of water and mixed for 30 seconds at second speed to dissolve the sugar. This is followed by the addition of superglycerinated shortening, flour, nonfat milk solids, baking powder (reduced 25 percent) and salt, the ingredients being mixed for five minutes in second speed. The remaining water, eggs and flavoring are then added and mixing is completed in first speed for one minute. Because this procedure results in greater aeration, a reduction in the amount of leavening or an increase in moisture (water) by 15 percent is required. Cakes obtained by this method are said to have a better crust color, a more tender crust, less indication of undissolved sugar in the crust, and better volume than the control cake mixed by the conventional method. The improvement in cake character is attributed to the use of dissolved sugar, which approaches the beneficial effects obtained by the use of liquid sugar.

In the so-called emulsion method, which is especially suited for large cake mixing machines, the sugar and shortening are first creamed together for 2 to 3 minutes until a smooth mass results. The milk is then added in two or more portions with beating at second speed continued until a fluffy mass resembling butter cream results. This is attained in about 5 minutes. Next the flour is added with a 2 minute duration for this stage, followed by the addition and mixing of the eggs for an additional 4 to 5 minutes. The total mixing time is thus 12 to 15 minutes.

The mixing of angel food cake is discussed in greater detail in the section dealing with its production. Whereas aeration in angel food cake is obtained by the formation of a protein foam consisting of air and egg white proteins, sponge cakes made with whole eggs depend upon the ability of the egg yolks to form a stable foam. Yolks contain a considerable proportion of fat which occurs in an emulsified state. The presence of fat, protein and lecithin in the yolk impart to the yolk solids an unusual extensibility which accounts for its ability to from a foam. When air is whipped into whole eggs the air cells are surrounded by yolk substance. The degree to which such a foam can be built up is governed by such factors as the temperature of the eggs, which should be within the range of 75° to 80° F., the sugar concentration, which should not exceed a ratio of 1.25 lbs. of sugar to each lb. of eggs, the original quality of the eggs, and the yolk solids concentration. While separated yolks contain too much solids to whip properly, whole eggs as a rule show a deficiency in yolk solids so that it is a common practice to add 20 to 50 percent of yolk to whole eggs to attain maximum foam volume and stability. Sponge cake batters may be mixed in different ways. Thus some bakers separate the whites and the yolks and whip each with a portion of the sugar, blending the mixtures after they have reached the desired light-

ness. The usual procedure, however, is to beat the eggs, tempered to a temperature of approximately 80° F., with a wire whip at medium whipping speeds, with the sugar added either directly or in a slow stream. After the egg foam has attained the proper lightness, the liquid and flour are folded in as lightly as possible to avoid a breakdown of the foam structure. It is essential that the utensils used in the handling of sponge cake batters be free of all traces of fat to avoid impairment of the whipping qualities of eggs. In so-called short sponge cakes in which either shortening or butter is used to impart better eating and keeping qualities to the final product, the fat must be added at the final stage of mixing to minimize the loss in volume.

FIG. 111—Mixing head of the Oakes continuous mixer. (*Courtesy American Machine & Foundry Co.*)

A radical departure from conventional mixing procedures is represented by the continuous mixing process which has been applied to the mixing of cake batters, marshmallows and icings (*196, 197*). The specially designed mixing unit has a relatively small mixing chamber with two identical heads, comprising the front and back stators. Each stator is equipped with concentric rings having a large number of fine teeth. Between the two stators is a rotor also comprised of concentric rings of moving teeth. A feed pump feeds the premixed ingredients into the mixing chamber in which the rotor is revolving at controlled speed, bringing about thorough mixing of the ingredients. At the same time, compressed air is forced into the chamber under controlled pressure, ensuring entrapment into minute bubbles of uniform size. The result is a batter characterized by an increased stability, greater uniformity, improved liquid carrying capacity and finer cell structure.

A continuous mixer of an entirely different design consists of a series of cylinders or tubes, one within the other. The outermost shell is of stainless steel sheet metal and encloses a layer of insulation. Then come two concentric tubes, one centered within the other. The space between them is occupied by the heat-transfer medium. Inside the smaller tube is the central rotating cylinder provided with hundreds of small blades. The cake batter to be mixed flows in the space between this cylinder and the enclosing tube. By revolving at a rate of approximately 800 r.p.m. the rotor with its blades provides for thorough emulsification. In practice the bat-

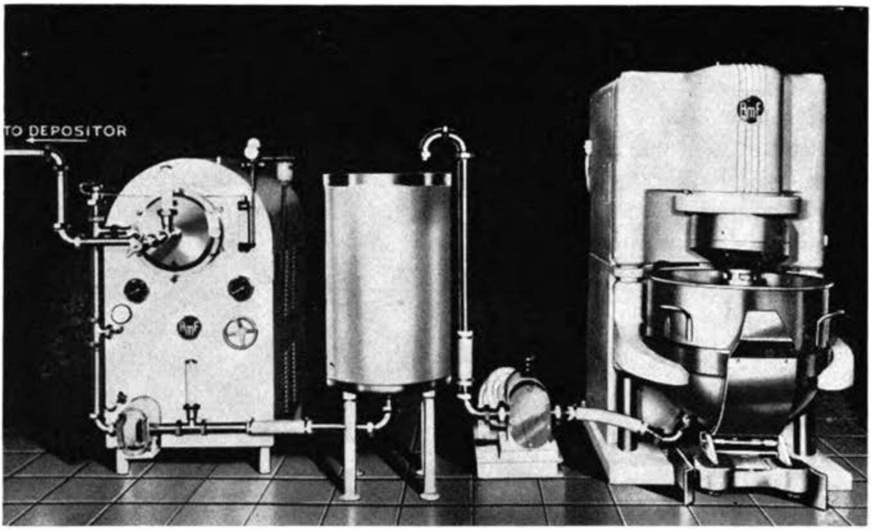


Fig. 112—The Glen-Oakes system of continuous mixing consisting of premixer (right), holding tank (center) and the Oakes unit (left). (*Courtesy American Machine & Foundry Co.*)

ter ingredients are premixed into a slurry which is then fed by means of a pump into the mixer with simultaneous injection of compressed air. The whipping action of the rotor blades under a sustained air pressure produces a fine emulsion which is then transferred from the mixer to the scaler by means of a sanitary pipe. In this system the temperature, pressure and rate of flow are under automatic control (*198, 199*).

BAKING OF THE CAKE

The mixed batter should be deposited into cake pans and baked with as little delay as possible. It must be kept in mind that once the baking powder constituents have entered into solution they begin to react and evolve carbon dioxide gas. In a fluid batter, this gas tends to gravitate upwards, the tiny bubbles coalescing as they come into contact with each other to form larger cells with a greater buoyancy. There is an inevitable escape of carbon dioxide gas from the batter as well as a coarsening of the cell structure if a mixed batter is kept too long out of the oven. Whenever possible, an automatic depositor should be used which can be adjusted to deposit a predetermined amount of batter into cake pans of a given size. These units operate efficiently and accurately, and with a minimum handling of the batter.

The oven temperature at which cakes should be baked will vary over a considerable range, depending on such factors, among others, as rich-

ness of batter, size of pan, and moisture content of the batter. Batters high in sugar content require low baking temperatures in the range of 325°-350° F., while leaner mixtures may be baked off at temperatures ranging from 350°-400° F. Baking time must be adjusted to baking temperature in an inverse relation, i.e., the higher the temperature, the shorter the baking period. It is essential that the baking time be kept to a minimum practical duration, consistent with thorough baking, to preserve as much moisture in the cake as possible. In general, the following temperature ranges will be found applicable to various types of cakes:

White layer cakes	350°-360° F.
Yellow layer cakes	350°-360° F.
Pound cakes	300°-350° F.
Foam cakes	325°-350° F.
Fruit cakes	300°-350° F.

The wider temperature ranges encountered with the pound and fruit cakes are due largely to the fact that these types of cakes are produced in weights varying from 1 pound to 3 or more pounds. The heavier units must necessarily be baked at lower temperatures to prevent scorching of the crust, and for much longer periods to obtain thorough baking than the lighter units. Layer cakes, on the other hand, are generally scaled to more uniform weights. This minimizes the need for wide temperature fluctuations and requires only minor adjustments in the baking time. Under normal conditions, the baking time for layer cakes will average 20 to 25 minutes; for pound cakes 60 to 75 minutes for 1 lb. loaves and up to 2 hours for 3 lb. loaves; and for sponge cakes, 45 to 60 minutes.

ANGEL FOOD CAKE

Angel food cake represents one of the simplest types of cake from the standpoint of formulation, containing only three basic ingredients: egg white, sugar, and flour. These are present in proportions of approximately 42 percent egg white, 42 percent sugar, and 15 percent flour, based on total batter weight, with very minor amounts of salt, cream of tartar and flavoring.

The typical composition of angel food batter obtained by the formula shown on page 615, which is well balanced by normal standards, shows the unusually high sugar content of this type of cake. This high sugar content is made necessary by the fact that sugar is the only tenderizing agent used, the other two basic ingredients, namely egg whites and flour, both acting as contributors of toughness to the cake.

Since cake baking has proven less adaptable to standardization of methods than bread and still involves a great deal of subjective judg-

ment with respect to the product's qualitative aspects, it is quite impossible to outline any one production procedure that will find general acceptance among bakers. While this state of affairs tends to give rise to a certain amount of confusion, it is not quite as detrimental to product quality as would at first appear because most types of cakes can be successfully made by one of several methods. Angel food cake is no exception to this. Thus Peterson (*200*) has found the following four different

TABLE 129. COMPOSITION OF ANGEL FOOD CAKE BATTER

	Formula	Percentage on flour basis	Percentage on batter weight basis
Flour	10 lbs.	100	14.5
Sugar	29.1 lbs.	291	42.1
Egg whites	29.1 lbs.	291	42.1
Salt	0.45 lbs.	4.5	0.65
Cream of Tartar	0.45 lbs.	4.5	0.65
Batter weight	69.10 lbs.		100.00

ways of combining flour and sugar with the beaten egg whites to produce successful results: (1) Adding all the sugar first, followed by the flour; (2) adding half the sugar first and the remainder with the flour; (3) adding all the sugar with one-third of the flour first and then the remainder of the flour; and (4) adding all the sugar with the flour. As Barmore (*201*) could show not all of these methods gave equally satisfactory results and his own recommended procedure is as follows: The whites of fresh eggs should be beaten, with about 1 to 2 percent cream of tartar, to a specific gravity of not less than 0.150 and not more than 0.170. Part or all of the sugar should be added to this foam and *beaten* in for about 30 seconds. Then the flour and any remaining sugar should be added and *stirred* in just sufficiently to insure even distribution throughout the batter. The batter then should be placed in a pan and baked at 350° F. for about 30 to 40 minutes, depending upon the size of the cake. In commercial practice, the general procedure is to whip the egg whites, to which the salt and cream of tartar have been added, at medium speed until the whites begin to form body, at which point from 50 to 60 percent of the total sugar is gradually added in a slow stream, with whipping continued until the meringue retains a "wet" peak. The flavor ingredients are added next, followed by the flour and the balance of the sugar which have been sifted together three times. At this latter stage, mixing is carried just far enough to obtain uniform distribution of all ingredients without causing an excessive reduction in the volume of the batter.

The basic factor in angel food cake production is to incorporate the in-

gredients with the beaten egg whites in such a way as to mix them thoroughly but without losing the air held by the egg foam. Barmore (*201*) has shown that maximum cake volume is obtained when the egg foam specific gravity was between 0.150 and 0.170. Above 0.170 the foam contained insufficient aeration to produce a light cake, whereas below 0.150 the stability was reduced to a point where considerable shrinkage occurred. As pointed out by this investigator, two opposing effects are operating as the beating of egg whites progresses. "One is the tendency to increase the cake volume because of the increasing amount of air incorporated; the second, the tendency to decrease the cake volume because of the decreased foam stability. When the egg white foam specific gravity is between 0.170 and 0.150, these two effects are approximately balanced."

It has long been recognized that a small amount of acid is a necessary ingredient for the production of angel food cake. In current practice, the acidifying agent generally used is potassium acid tartrate, commonly known as cream of tartar. Grewe and Child (*202*), investigating the effect of potassium acid tartrate as an ingredient in angel food cake, found that whereas a fine-grained, white cake is obtained when cream of tartar is used as a part of the ingredients, its omission results in a yellow and coarse-grained product. Since similar improvements in both grain and color were obtained by the use of citric, malic and tartaric acids, these investigators concluded that the beneficial results were due largely to the acidity, which approximated a pH value of 6.6. According to Barmore there are at least two favorable and necessary effects produced by acid: the first is the stabilizing of the foam so that the heat during baking may have time to penetrate and the temperature of coagulation be reached before the foam has collapsed sufficiently to produce large air cells, and the second is the prevention of the extreme shrinking of the cake during the last part of the baking period and during the cooling period. The practical result of the first effect is a fine, even grain, and of the second effect a large finished cake volume. The use of acid also perceptibly whitens the color of the crumb. While it appears that the beneficial effects obtained by the use of acidifying agents is due to their keeping the pH of the batter on the acid side, not all acids are equally efficacious. When the effects produced by acetic or citric acid are compared with those obtained with potassium acid tartrate, it will be observed that in the case of the first two acids the stabilizing effect is more or less absent so that they do not produce as fine a texture as does the tartrate, although they do prevent the extreme shrinkage of the cake. Since superior results are obtained with cream of tartar from both the stabilizing and shrinkage preventing viewpoints, this material is commonly used as

the acidifying agent in angel food production. The addition of 1.5 to 1.75 percent of acid based on the weight of the egg whites will usually produce a pH which is well within the optimum range of 5 to 6.5 for angel food cake. Some adjustment in the amount of acid ingredient is generally required when egg whites subjected to long storage are used since the pH of such whites may vary from 7.6 to as high as 9.6 (*203*). Obviously, such variability in the pH of egg whites is bound to be reflected in a noticeable non-uniformity of cake characteristics unless some control is exercised by means of a close adjustment of the amount of acid material used to produce the desired pH level in the cake. In addition to changes in pH values, apparently other properties of egg whites are modified with prolonged storage since it has been repeatedly shown that eggs several days old do not yield as good results in angel food production as do fresh eggs. Barmore (*201*) attributes the reduction in the baking quality of stored eggs to a protein hydrolysis that occurs during aging and which results in a liquefaction of the egg whites. Kahlenberg (*204*) more recently compared the performance in angel food production of egg whites from eggs held at summer temperatures (86° F.) for time periods ranging from 0 hours to 6 days after gathering, followed by storing at 44° F. Baking tests showed that holding eggs at summer temperatures for 3 to six days produced a marked coarsening of the grain and pronounced shrinkage of the cake.

While different investigators have at times recommended baking temperatures for angel food production which varied over a fairly wide range, the current consensus is that optimum results are obtained by adhering to the practice of baking the angel food at the highest temperature consistent with the shape and weight of the cake and in the shortest period of time. Recommended baking temperatures are 350°-360° F. for large 22 to 26 oz. cakes, and 375-400° F. for the smaller 10-14 oz. cakes. Barmore investigated the effect of different baking temperatures on cake quality by subjecting a series of cakes to oven temperatures varying from 280° to 356° F., baking each cake for a period that resulted in as nearly an identical crust color as possible. He found that as the oven temperature increased, the cakes improved in both volume and tenderness. There was no development of toughness as was suggested by Halliday and Noble (*168*) who felt that more tender cakes would be obtained by baking at low temperatures because egg white which has been coagulated at lower temperatures is more tender than that coagulated at high temperatures. Barmore, however, has found that the interior cake temperature does not change appreciably regardless of oven temperature employed. Thus in one series of bakes in which the difference between low and high oven temperatures was 72° F., the internal cake tempera-

ture varied only by 3.6° F. The higher the temperature employed, the shorter the baking time. There exists also a direct positive correlation between baking temperature and cake volume, the volume increasing practically proportionally with the oven temperature. On the other hand, the relation between oven temperature and amount of evaporation is inversely proportional, i.e., the higher the oven temperature, the smaller the evaporative loss which occurs during the baking period and the more moist the final product is.

The ultimate quality of angel food cake is determined to a considerable extent by the care with which the operator attends to certain relatively minor, but nonetheless important, details during the preliminary handling of the various raw materials. Many of the more significant points in this connection have recently been discussed by Thelen (*205*). There is, for example, the effect of temperature on the whipping characteristics of egg whites. It may be stated as a general fact that egg whites of comparable quality will whip into a foam over a fairly wide temperature range. Thus, if a sample of egg whites were to be divided into several portions and each adjusted to a different temperature within the range of about 40° to 100° F. and whipped, each would yield approximately the same type of foam. It would be found, however, that the whipping time required to reach a given specific gravity would differ considerably with different temperatures. This relation of whipping time to egg white temperature is shown in the graph on page 619.

The generally recommended temperature for egg whites at the time of whipping is 70° to 75° F. To maintain this temperature range during warm summer months requires some care and the danger of over-whipping is always present once shop temperatures exceed 85° F. The higher the temperature of the egg whites, the more critical the whipping time becomes and it is usually good practice, when working at high shop temperatures, to adjust the temperature of the egg whites to 45° to 50° F. An additional reason for controlling the temperature of the egg whites to within a range of 50° to 70° F. is that this range yields the highest cake volume. Temperatures below 45° F. and above 75° F. result in a marked lowering of cake volume.

Fresh frozen egg whites are preferably thawed out in a cold water bath, although they may also be thawed out at room temperature. In the latter case it is necessary to anticipate production requirements a day ahead since it usually requires about 24 hours to thaw frozen whites at room temperature. One should never place the cans of frozen whites near an oven or into a hot water bath to accelerate thawing as the high temperatures exert an adverse effect upon the whipping properties of the whites and tend to cause their rapid bacteriological deterioration. The thawed

FIG. 113—Time study for angel food batter at variable starting temperatures of egg whites. Air temperature: 75° F.

whites should be thoroughly stirred to obtain a uniform distribution of the thin and thick portions which usually segregate during freezing, the thick whites tending generally to migrate into the center of the container, while the thin whites comprise the outer portions of the contents.

The whipping quality of egg whites varies with viscosity, the less viscous thin whites giving a foam more quickly and in greater volume than the more viscous thick whites. On the other hand, foams obtained from thick whites possess greater stability. According to Almquist and Lorenz (*206*) the firm white is composed of a fine, fiber network of pure ovomucin in which is entrapped the thin white. As the carbon dioxide escapes, the fibers break up and can no longer entrap the liquid quite. The difference between thin and thick whites is considered by these workers to be one of structure rather than of moisture content and it has been shown that the total solids content of the thin egg whites is equal to that of the firm whites.

Miller and Vail (*207*), in a study of fresh and frozen egg whites in angel food cake production found that fresh whites, frozen thick whites and frozen thin whites whipped best at a temperature of 70° F. The resultant foams were stable and all of the cakes were more tender and

of better texture when they were made from whites whipped at this temperature. The thin frozen whites whipped more quickly than the thick frozen ones, and both types whipped more quickly than the fresh whites. Both the thin frozen and the fresh whites produced cakes of high quality with similar characteristics, but those made from thick frozen whites were less desirable.

In the event that fresh shell eggs are used in the production of angel food, great care must be exercised to obtain a clean separation of the yolks from the whites. Even traces of yolks in whites have a marked volume-reducing effect on the whipped whites. This foam-destroying action of egg yolk is attributed to the relatively high fat content of the yolk. The same effect is produced by traces or films of fats adhering to bowl or utensil surfaces that come into contact with the egg whites during whipping. For this reason it is imperative that bowl interiors and whips are absolutely free of grease or fat of any kind. This is best accomplished by washing the bowl and other utensils in hot water with a suitable mild soap compound or an approved cleaning solution and rinsing them well. The manner in which the rinse water drains off affords an indication of the degree of freedom from fat. If the rinse water forms tiny rivulets, it betrays the presence of fat films on the surfaces of the equipment.

Several additional points relating to angel food production may be mentioned as possessing some practical significance. In beating the egg whites, the use of medium speed will generally be found to produce the best cakes. Egg whites vary considerably in the time they require to attain the proper specific gravity so that it is quite impossible to specify a definite beating time. The reason for recommending the use of the medium speed is that it is easier to prevent overbeating of the whites when they are being beaten at a moderate speed than when they are subjected to high speed beating. Overbeaten whites result in cakes that expand considerably in the oven during the initial period of baking and which undergo marked shrinking just before baking is completed. It is well to check on the mixer to see that the whip reaches the bottom of the bowl so that there does not remain a deposit of unbeaten egg whites which can subsequently have an adverse effect on cake quality. The incorporation of the flour and remaining sugar into the beaten whites should be carried out carefully, whether done by machine or by hand, to effect thorough distribution. When mixing is done by machine, it is good practice to finish the operation by hand so as to ensure that no flour sediment is deposited on the bottom of the bowl.

Some bakers, in the interest of obtaining a moist and close-grained cake, follow the practice of adding water to the whites during the whip-

ping stage. Addition of water is limited to a maximum amount of 4 ounces per quart (2 lbs.) of whites. While this practice results in a slight reduction in cake volume, it does have the beneficial effects of imparting to the baked product a close grain and a more moist crumb. It is frequently desirable to prevent the excessive coloration of the crust. It has been found that wetting the interior surface of the baking pans prior to filling with the cake batter tends to lighten the crust color. It is generally felt that when the batter is deposited into dry pans sugar caramelization proceeds at a more rapid rate than when the baking surface is first moistened. A more uniform cell structure will be obtained when the pans, after being filled, are tapped lightly on the bench so as to eliminate any large air pockets. While this procedure might result in a very slight loss of volume, the elimination of unsightly holes in the crumb amply justifies this practice. The same effect may be obtained by giving the batter, deposited in the pans, a rest of approximately 30 minutes. During this period, the batter tends to settle somewhat, with the large air cells rising to the top and being thereby eliminated.

CHAPTER XXV

MISCELLANEOUS BAKED PRODUCTS

FRIED CAKES OR DOUGHNUTS

The commercial production of fried cakes, or doughnuts, while greatly simplified by the introduction of prepared flour mixes, special frying fats, and semi-automatic and automatic frying equipment, still calls for close control of processing, from the storage of raw materials to daily evaluations of yields, if quality products are to be obtained. Thus the ingredients, whether in the form of prepared mixes or as separate materials, require proper storage in cool, well-aerated rooms. In mixing doughnut batters care must be exercised to attain the proper absorption, correct batter temperature and adequate mixing. As a rule it is a safe policy, when prepared flour mixes are used, to follow the mixing instructions supplied by the manufacturer to assure uniformity with successive batches. The principal variable is introduced by the frying operation in which such factors as type of frying fat, rate of fat replacement, and frying temperature level require special consideration.

Although most hydrogenated fats are suitable for frying, the tendency has been to favor the vegetable fats. This does not mean that the meat fats, properly hydrogenated and treated with anti-oxidants, such as gum guaiac, are inferior to vegetable oils. For all practical purposes, their suitability is equal to that of vegetable fats and they have the added advantages of a slightly higher smoke point and a greater resistance toward foaming as compared with common hydrogenated vegetable oils (*208*). On the other hand, the manufacturers of prepared doughnut mixes have for various reasons shown a preference for vegetable oils.

To be suitable for frying, a shortening must meet the following general requirements: It must allow normal structural development of the doughnut; it must not impart any undesirable flavors to the fried products; it must congeal sufficiently during doughnut cooling so that the fried product will not subsequently "sweat"; it must be stable over extended frying periods at relatively high temperatures; and finally, it should have a short pre-quality period. It has been found that the degree of saturation has a marked effect upon a fat's performance in doughnut frying. Normally, a fresh frying fat does not yield properly devel-

oped doughnuts until a certain frying period has elapsed, the length of this period varying with different types of shortenings. The appearance of the point in usage at which the shortening functions properly is called the quality period and this point may be correlated with the increase in free fatty acid content. There is, however, no particular percentage of free fatty acids which indicates this point for all shortenings. Arenson and Heyl (*209*) have reported that the greater the saturation of the fat used, the longer is its pre-quality period. They found, for example, that in the case of a fully hydrogenated cottonseed shortening, a free fatty acid content of 0.35 percent was reached in the fat before quality doughnuts resulted. A partially hydrogenated cottonseed shortening developed a free fatty acid content of 0.25 percent, while a corn oil, and oil and stearin mixtures, contained only 0.1 percent before they functioned normally. The addition of fatty acids to regular shortenings practically eliminated the pre-quality period. According to the same authors (*210*) under commercial conditions a fat which has reached its quality period will have a fatty acid content on the order of 0.5 percent and this fatty acid content will vary indefinitely between 0.5 to 0.8 percent where replacement of shortening absorbed by the doughnuts is practiced.

Recommended frying temperatures range from 365° to 380° F. Temperatures very much in excess of this range will cause accelerated breakdown of the frying fat and pronounced smoking, and will also impart too dark a crust color to the fried product. On the other hand, temperatures below this range will yield pale colored products and an excess absorption of fat.

Fresh frying fats usually have a smoke point in the neighborhood of 450° F. As heating continues, the smoke point is progressively reduced until it comes within the range of normal frying temperatures. Although the actual loss of fat through smoking and volatilization is insignificant, excessive smoking is obviously undesirable and indicates advanced deterioration of the frying medium. The rate of fat breakdown is increased by permitting the level of the shortening to fall below the recommended point in the frying unit. This condition is avoided by proper attention to the float valve which controls the flow of fresh fat from the reservoir into the frying kettle. The fat in the reservoir, located above the kettle, should be thoroughly melted before it is used for replacement, otherwise the lower-melting fractions will concentrate in the frying medium and alter its characteristics. Where the frying unit is not equipped with a fat reservoir, thus requiring the manual addition of the replacement, the fresh fat should first be melted down slowly and by a method that will not overheat it. The addition of solid fats to the frying medium should by all means be avoided since such procedure results in a marked reduc-

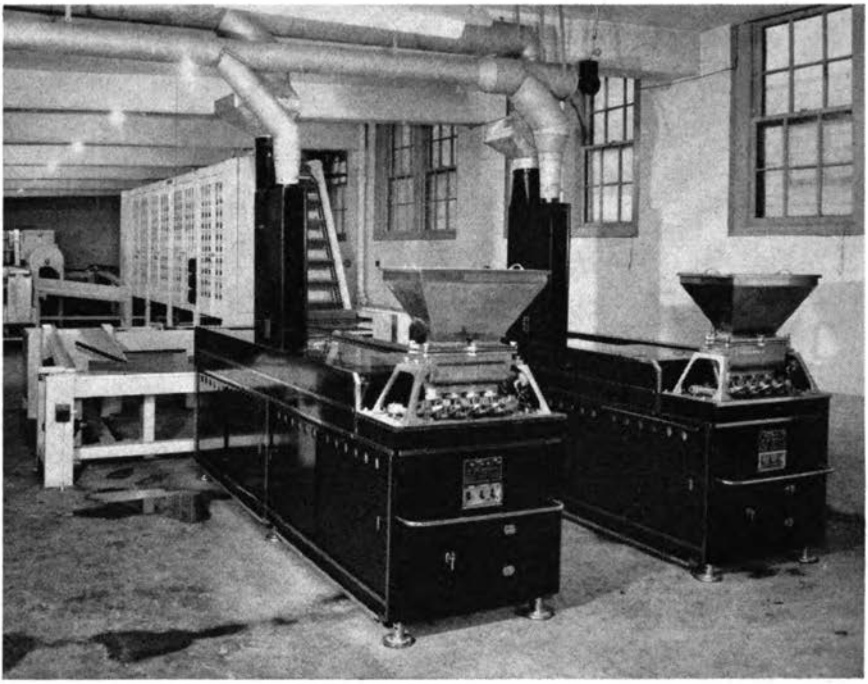


FIG. 114—Automatic doughnut frying units. (*Courtesy Joe Lowe Corp.*)

tion of the temperature and consequent disturbance of operation. It is good practice to strain the frying fat periodically through a close meshed cloth to remove particles of carbonized dough which inevitably accumulate in the frying medium.

Everson and Smith (*211*) have reported the following composition of the finished doughnuts with an average weight of 30 grams:

TABLE 130. COMPOSITION OF DOUGHNUTS

Protein	1.84 g.
Fat	6.03 g.
Carbohydrate	14.70 g.
Calcium	13.40 mg.
Phosphorus	92.70 mg.
Iron	0.57 mg.
Thiamine	0.085 mg.
Riboflavin	0.066 mg.
Niacin	0.600 mg.
Moisture	6.84 g.
Calories	123.6

Comparing the vitamin content of the dry doughnut mix with that of the fried product and making due allowance for the addition of water

and fat absorption, these authors found an average loss of 22.9 percent in the case of thiamine and 20 percent in niacin, with no measurable loss in riboflavin.

PIE PRODUCTION

Pie Flour. The type of flour generally recommended as being best suited for pie doughs is unbleached pastry flour milled from soft wheat varieties. Soft white winter wheats supply the greater portion of commercial pie flours, although soft red winter wheats are also milled for this purpose. According to Bisno (*212*) the red wheat flours usually show somewhat stronger characteristics than do white wheat flours, the doughs made from the former requiring more shortening as well as longer baking than do those made from the latter. Since soft flours are used for the primary purpose of obtaining a tender crust, any treatment of the flour which might act to strengthen its gluten is preferably avoided. This includes normal bleaching of the flour. An excessive amount of bleaching agent is occasionally employed to weaken the gluten of a flour possessing strong characteristics which, for this reason, would otherwise be unsuitable for pie baking. However, flours given such excessive chlorine treatment frequently produce extremely sticky doughs which are very difficult to handle during production. Furthermore, excessive bleaching may impart a dull, grayish color to the flour which is often carried over into the dough made from it. If pastry flours are unavailable, it is generally preferable to use regular bread flours, properly modified, for pie doughs. Since the chief objection to bread flours is their comparatively high protein content, a widely employed corrective measure is to replace up to 20 percent of the bread flour with corn starch or rice flour which are relatively free of protein. A flour modified in this manner will usually require slightly greater amounts of shortening and liquid ingredients to adjust for the greater strength and higher absorption capacity of the hard wheat gluten (*213*). Good pastry flours intended for pie baking should possess a pH value of 6.0. Low pH values, such as those approaching 5.0, indicate excessive bleaching with a concomitant weakening of the gluten which manifests itself in sticky doughs and a soft baked crust.

Shortening. Shortening represents the most expensive ingredient in a pie dough. It also plays a highly significant role in developing the final structure, texture, and appearance of the baked crust. The kind of shortening employed in pie production is very frequently determined by the personal practical experience of the baker. Lard has long been used for pie baking because of its excellent shortening characteristics, its desirable plasticity, and its tendency to spread in a manner that promotes the formation of flakiness. It also contributes a flavor to the finished crust which is found highly acceptable by most consumers. The principal ob-

jection to lard, as pointed out by Bisno (*214*), is the great variability in the melting point, flavor and keeping quality of the commercial product, a variability that results from differences in the type of feed used for the hogs, the body source of the fat, and the method of rendering the lard (*cf.* pages 281–2). For this reason hydrogenated vegetable shortenings, whose uniformity with respect to such properties as plasticity, shortening power, and freedom from flavor, is more readily maintained, are finding increasing application in pie production. The selection of the proper type of shortening must take into consideration the many factors which tend to influence its performance, such as average temperature and humidity conditions, available of suitably conditioned storage space, type of equipment used, kind of crust desired, and others. Obviously the same shortening will not yield equally good results when used in, say, a mealy crust and a long flake crust, since these two types of crust demand different characteristics in the shortening. In sections of the country where the mean temperature is subject to pronounced seasonal changes, some adjustments in the properties of the pie shortening must be made as production moves from the cold season to the warm season.

Water. Although water is generally accepted as a constant ingredient, it may be subject to considerable variation in pH, and in its organic and mineral contents, as has been amply indicated in a more detailed discussion elsewhere in this volume (*cf.* pages 353 *ff.*). Many of the apparently inexplicable difficulties that develop in pie production have their cause in unrecognized changes in the character of the water. Hence when water is drawn from supplies which are known to undergo periodic or seasonal changes, the frequent analysis of the water becomes an essential control measure. In its use as a dough ingredient, the water should be chilled for best results. Where available, ice water is recommended for the hardening effect it has on shortening. Such hardened shortening, by resisting uniform dispersion during mixing, will contribute toward the formation of flakiness in the finished crust. Crust flakiness is established during the flour-fat blending stage; when chilled water is subsequently added the particles of shortening will harden and maintain themselves intact during the dough mixing stage.

Salt, Milk, Etc.: Salt is used for the primary purpose of accentuating the flavor of the crust, its omission resulting in an insipid, flavorless crust. While variations in the percentage of salt added exert a slight effect upon dough consistency, this variable is too small to be of practical significance. Only commercially pure salt should be employed for pie dough. The salt is preferably dissolved in the dough water to assure uniform distribution on the one hand, and a minimum strengthening of the gluten on the other.

Milk in any form contributes to the quality of the crust by improving its color and increasing its nutritive value. Maximum beneficial results are obtained by the use of 2 to 3 percent of milk, based on flour and calculated as dry milk solids. One shortcoming of the use of milk, according to Bisno (*214*), is that it promotes soaking of the bottom crust under summer or otherwise warm conditions. This tendency may be reduced by first heating, and then cooling, the reconstituted milk prior to its use in the pie dough. Crust coloration during baking may also be improved by the use of small increments of corn sugar or cerelose in the dough formula.

The use of baking powder for the purpose of reducing crust shrinkage has gained wide acceptance among pie bakers. As a rule, the amount is limited to less than 1 percent of flour weight. In practice, it is sifted into the flour to obtain even distribution.

PIE MIXING PROCEDURES

The making of the pie dough involves two steps: (1) a light mixing or blending of the flour and the shortening; (2) the addition of the water to the flour-shortening blend and further light mixing until the dough just holds together. The actual mixing procedure adopted is governed by the type of crust desired, of which three basic varieties are distinguished, namely, the mealy crust, the short-flake or moderately flaky crust, and the long-flake crust obtained by rolling the dough.

To obtain the mealy-type crust, the flour and shortening are rubbed together or mixed fairly extensively so as to yield a pasty blend in which the flour particles are more or less completely enrobed by the fat. The chilled dough water, amounting to about 25 percent based on flour weight and containing the salt, sugar, and other additives, is then added and lightly mixed in. The finished dough should have a wet grainy appearance. To complete water absorption, the dough is then stored in a room cooled to 60° F. or lower for a period ranging from four hours to overnight. This rest permits the gluten to become modified through enzyme action, yielding thereby improved dough characteristics. Shrinkage and toughness in the finished crust are largely eliminated and the soaking tendency greatly reduced by this practice of resting the dough. A somewhat stronger flour may be used for this type of dough than is recommended for the flakier crusts.

The production of dough for the moderately flaky crusts calls for a softer flour and also a somewhat higher absorption than is used for mealy crusts. Here the blending operation must be stopped somewhat sooner than in the previous case so as to retain a good proportion of the shortening in the form of very small discrete particles distributed throughout the

mix. The water is then added with the salt and sugar or milk and the dough mixed until it holds together. In general, the finished dough will hold together much better and possess a drier feel than the mealy type dough. Although it is possible to mix the dough to a point where it can be used immediately, it is preferable to reduce the mixing time and subject the dough to a rest period as recommended above.

In the production of the dough for the long-flake type of crust, it is essential that a rather firm shortening be used which is broken up into small pieces approximating 1 inch in diameter and one-fourth inch thick. The firmness of the fat should be sufficient to prevent its subsequent breakdown during the blending stage of the process. The flour and shortening should be mixed lightly, after which the water is mixed in just enough to have the dough hold together and give it a fairly dry feel. The dough is then divided into small batches which are rolled to a thickness of about 2 inches, then folded twice in one-third sections to yield a three-layer dough six inches thick, and the rolling and folding process repeated twice. After that, the dough is again rolled to a thickness of 2 inches and placed into an icebox or a cool room for several hours or overnight. This procedure yields a crust with large flakes and an excellent oven spring.

One of the main points to observe in the handling of pie doughs is the avoidance of over-mixing with its adverse effects. Over-mixing causes excessive gluten development which contributes to crust toughness and shrinkage on baking. It is also undesirable for causing too thorough a fat dispersion, especially when mixing is carried out with warm ingredients, which tends to destroy the flaky character of the crust. The practice of extending the mixing process to yield a dough which can be used immediately has little to recommend it. Superior results will always be obtained when mixing is held to a minimum and the dough subsequently given a rest to complete hydration and mellowing.

THICKENERS

Although the variety of pie fillings is legion, there are two basic types, namely (1) the fruit fillings and (2) the milk or water fillings, often referred to as soft pie fillings. The vast majority of fillings make use of some kind of thickening agent, usually starch, to give them the desired body and consistency. Not all starches are equally suited for this purpose. While specially processed corn starch is most widely used at present, other types of starches, such as tapioca, waxy maize, potato, and rice, also give as good or better results. The thickening agent may also be one of several vegetable gums, such as agar-agar, alginate, tragacanth, karaya, arabic, etc., which yield clear gels. Because of their rela-

tively high cost, however, these latter substances are only rarely used.

Trempel (*215*) suggests the following properties for a starch intended for pie baking: It should (a) gelatinize with a minimum time of cooking; (b) yield a good gloss and transparency; (c) resist the action of fruit acids; (d) be without effect upon the fruit flavor and color; and (e) when the starch gel is cooled, be free of cereal taste, have shortness, and possess a syrupy, semi-solid consistency.

Common commercial practice is to pre-cook the fruit filling, thereby greatly reducing the actual pie baking time. Depending upon the type of fruit, the cooking operation may include either the fruit itself or only the drained juice, with the various added ingredients. The procedure in both instances is to place the fruit or the juice into the cooking kettle, add the necessary water and part of the sugar, and bring the mixture to a temperature of at least 190° F. or to a boil. The starch is added in the form of a suspension in gradual increments so as not to lower the temperature of the batch too much. The entire mixture should be stirred thoroughly until the starch gelatinizes and the mass becomes clear. The balance of the sweetener is then added, together with such additional ingredients as flavoring and coloring substances, and heating continued only to the point necessary to assure complete solution of the sugar. If the mixture includes the fruit, the cooked batch is cooled and is then ready for depositing in the pies. If only the juice was cooked, the fruit is then added to the boiled batch and gently stirred in. In some instances it may be desirable to reheat firm fruit to tenderize it or to prevent "bleeding" and possible fermentation. It is essential, however, that once the starch has been added the balance of the operation be carried out as rapidly as possible to avoid a breakdown of the starch gel by the heat and the fruit acids.

Generally speaking, starch gelatinization occurs most readily in pure water, the gelatinization temperature being within the range of about 155° to 170° F., depending upon the type of starch. When sugar is added to the starch suspension, the gelatinization temperature rises with progressive sugar concentration, until eventually a point is reached when incomplete gel formation results. In the preparation of pie fillings, the amount of sugar added to the initial mixture is therefore of considerable practical significance. If too much sugar is added, proper starch gelatinization is prevented and the resultant gel will be dull in appearance, thin in consistency and possess a pronounced cereal taste. If insufficient sugar is added, the gelled mixture tends to become too stiff for proper subsequent incorporation of the sweetener. Good commercial practice calls for a starch: sugar ratio of 1:3 to 1:3.5 during the starch gelatinization stage. In other words, for each pound of starch to be added, the

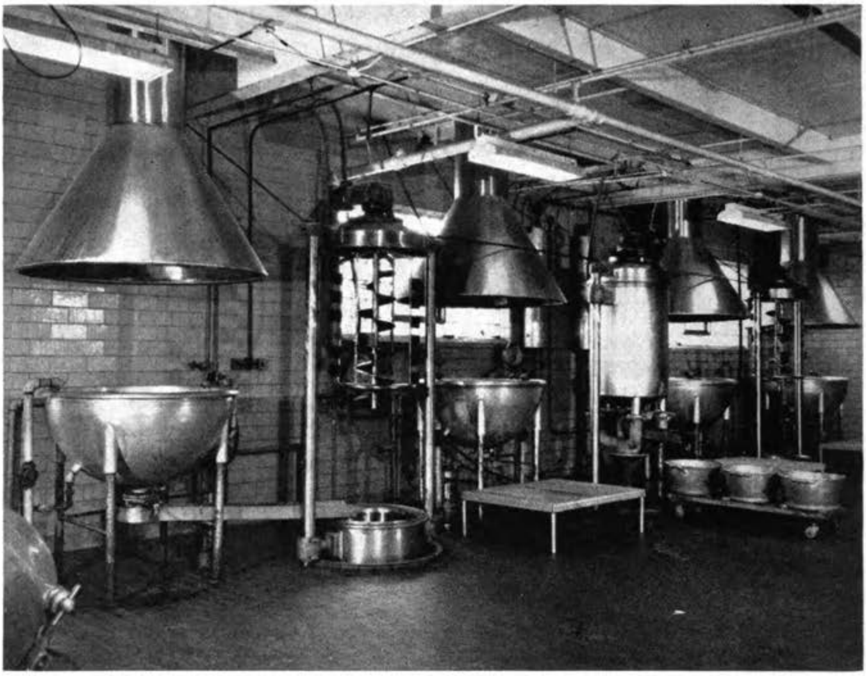


FIG. 115—Cooking room in a modern pie bakery. (*Courtesy Wagner Baking Corp.*)

batch of boiling fruit, juice, and water should contain from 3 to 3.5 lbs. of sugar. When frozen fruits containing variable amounts of sugar are used, it is preferable not to add more sugar until the gelatinization stage has been passed. Ordinarily, starch in amounts of 3 to 3¼ ounces per quart of juice or water, corresponding to a ratio of approximately **1:10** on a weight basis, is used for thickening. In plain water such a starch concentration would yield an excessively stiff gel. In pie fillings, however, the fruit acids, sweetener and fruit pulp all act to soften and tenderize the final gel. The higher the fruit content of a filling, the smaller is the amount of starch required to impart a desirable consistency and body to the filling. Thus, fruit fillings containing 50 to 60 percent of fruit will normally have a starch content of 2 to 4 percent of the total batch weight. With decreasing fruit content the starch content must be increased correspondingly to produce a filling with proper body, handling quality and shelf-life.

In the preparation of the so-called soft pie fillings, which include the puddings and custard creams, the same general procedure outlined for fruit fillings is followed. In plain water or milk fillings, the starch concentration is preferably reduced to 8 ounces per gallon of liquid. If egg

is used, the starch content is further reduced by 4 ounces for each pound of egg because the egg acts as a thickening agent. On the other hand, if this type of pudding or custard cream is to be beaten or stirred after cooling, or if butter, cream, or high amounts of sugar are to be added, the starch content should be increased to about 10 ounces or more per gallon of liquid. In lemon fillings the starch content should be increased to 12 ounces on the same basis. In the preparation of these types of fillings it is recommended that starch gelatinization be carried out in a solution of low concentration and that the rest of the ingredients, such as the balance of the sugar, eggs, flavoring, etc., be added after gelatinization has been completed.

When corn starch gels are allowed to stand for prolonged periods at normal or moderately low temperatures, they tend to undergo a change in their clarity, which diminishes markedly, and in their consistency, which is reduced by the separation of solid matter. These changes are associated with the well-known phenomenon of retrogradation which is particularly pronounced in corn starch and leads to the "drying out" of pie fillings in which this starch is used as the sole thickening agent. It is for this reason that other types of thickeners are used, either alone or in combination with corn starch. Among the starches, tapioca starch and waxy maize starch are the most widely employed. Tapioca starch produces a viscous, stringy, transparent gel of great moisture retaining capacity and resistance to retrogradation. When used in conjunction with corn starch as a thickening agent, even at a ratio of as low as 4 to 1, it is highly effective in augmenting the desirable properties of the corn starch and in minimizing its less desirable ones. The same holds true of waxy maize starch. It also produces a viscous, stringy gel with a transparency superior to that of a tapioca starch paste, an even lesser tendency toward retrogradation, and a more neutral flavor (*216*).

Other cereal and tuber starches are finding use as thickeners. For example, a new modified wheat starch of the highly purified thick-boiling type has been introduced commercially which, because of its unusual properties, is highly suited for use as a thickener and stabilizer in pie fillings. It produces a soft tender cream filling and yet is sufficiently acid resistant and transparent for use in fruit fillings, thus combining the individual advantages of corn starch and tapioca starch. The fillings have little tendency to become rubbery or to pull away from the crust and, more important, are free of the typical "starchy" cereal flavor (*217*).

Chlorinated tapioca starch yields a clear, tender gel with a minimum tendency toward retrogradation. Fruit fillings made with this starch generally possess a desirable transparency. Its gel being softer than that of corn starch, somewhat greater amounts of it are normally required.

It is usually used in combination with starches, such as tapioca and waxy maize, that yield viscous gels, the relative proportions of the two types of starch being governed by the flow characteristics aimed at in the filling. Potato starch gives a clear, soft gel. Because of its lower gel strength, about 15 percent more of potato starch must be used than of corn starch to yield gels of comparable consistency. Fillings made with potato starch as the sole thickener tend to thin on reheating in the oven. It is, therefore, common practice to use potato starch only in combination with other starches whose gels show greater heat resistance. The properties of sweet potato starch coincide rather closely with those of potato starch, except that its gel is perhaps slightly stronger and possesses a somewhat greater moisture retaining capacity. In practice its use is about the same as that of potato starch. Rice starch produces a soft clear gel possessing excellent moisture retaining capacity, but being rather sensitive to heat. Its use is, therefore, limited to soft pie fillings which are subjected to only slight oven treatment.

Among the vegetable gums, gum karaya and locust bean gum appear to find widest use as thickening agents. Gum karaya produces a soft, flowing gel suggestive of that obtained with tapioca starch, but being less heat sensitive. Locust bean gum sets to a thick gel with no tendency to flow. Both gums are normally used in combination with starches. Because of their lump forming tendency they are preferably mixed with the sugar before being added to the cold juice or fruit. The filling must be stirred continuously during heating and the starch is added as a suspension when maximum viscosity has been attained.

A detailed discussion of the viscosity characteristics of starch pastes and the influence exerted on them by the presence of electrolytes, different pH values, varying sugar concentrations, fats, etc., has been provided by Bisno (*216*).

The proper handling of the pre-cooked fillings prior to their use is of considerable importance to the quality of the final product. The fillings should be cooled as rapidly as possible in cooling devices designed specifically for this purpose. Rapid cooling will preserve the flavor, color and body of the filling. Improper cooling usually results when the batch is permitted to stand at room temperature or even when the entire batch is placed into a refrigerator since the center portion will remain at a high temperature for too long a period and cooling proceeds at an uneven rate. This causes such well-known faults as bleeding of the fruit, lumping of starch, and breakdown of the gel. Fruit fillings containing starch are unsuitable for low temperature storage except for short periods, as chilling of the fillings results in loss of clarity and stability. Under closely controlled conditions, however, it is possible to keep such pre-cooked

fillings for three to four days at temperatures of 50 to 60° F. Bakery supply firms usually added 0.1 percent of sodium benzoate as a preservative to prepared fillings (*215*).

PIE BAKING

The baking of the filled pies must balance two critical factors, namely the proper baking of the crust and the prevention of boiling over of the fruit filling. A good solid bottom heat and a medium top heat will provide the proper conditions in the oven necessary to attain the desired bake. As a rule the oven should be fairly hot for two-crust pies, most temperature recommendations falling within an approximate range of 425° to 500° F. For the baking of oven-filled pies, such as custard, pumpkin, etc., oven temperatures should be lower, i.e., within a range of 380° to 400° F. Fruit fillings should be adequately cooled prior to being deposited into the pie dough lining the pan. Excessively warm fillings will tend to melt the shortening dispersed within the dough in layers, causing it to be absorbed by the dough and thereby destroying the flakiness of the crust. Furthermore, warm fillings tend to reach the boiling point sooner than cool fillings, leading to underbaked, soggy crusts. In terms of time, a hot oven will cause a filling to boil sooner than will a cool oven. However, it will also prove more rapid in terms of crust baking. In general, crust coloration in a hot oven takes place at a more rapid rate than does the heating of the filling so that boiling over of the filling is a rare occurrence when relatively high oven temperatures are maintained. In the case of cool ovens, on the other hand, the baking time must be extended to obtain adequate crust coloration, thereby giving the filling sufficient time to reach boiling temperatures. The time required to bake the crust thoroughly is dependent upon a number of variable factors, such as the amount of sugar or milk used in the dough, amount of shortening incorporated, thickness of the crust, kind of fruit filling, type of wash used, and oven heat, so that no specific baking time can be recommended. Harder and Jabusch give in Table 131 averages of time and temperature for various types of pies which may serve as approximate guides (*213*).

The actual baking times and conditions adopted in a given plant are the result of practical adjustments to specific formula and equipment requirements.

In practice, the matured pie dough is divided, rolled or sheeted, and placed into the pie plates. These operations may be performed either manually, as is normally done in shops with low production demands, or mechanically by specially designed equipment. In the case of cream and custard pies, the crusts are baked prior to being filled. To prevent the

formation of blisters, the dough in this instance may either be docked or, if this is undesirable, baking may be done between two tins, one tin being placed over the dough. The use of perforated plates will also overcome the problem of blister formation. In the case of fruit filled pies, the filling is deposited into the dough-lined pan either by means of a dipper which measures out the correct amount of filling or, in the case of large scale production, by an automatic depositor. Care must be exercised not to splash fruit or juice onto the rim since this will interfere with obtaining a proper seal between the top and bottom crusts. The rim of the bottom crust is next wetted and the top crust placed over the

TABLE 131. PIE BAKING TIMES AND TEMPERATURES

Type of Pie	Temperature	Time
Cooked Pies		
Raw fillings	440-450° F.	35 min.*
Cooked Pies		
Cooked fillings	450° F.	30 min.
Shell Crust		
Empty	500° F.	12 min.
Shell Crust	450° F.	10 min.
Custard filling	and	
	325° F.	30 min.

* Fresh apple requires 45-60 min.

filling, the crust edges being sealed by a crimping machine or by hand. In this operation excess dough is trimmed off and the edge usually given a decorative effect.

There are certain obvious precautions and practices that must be followed in final dough handling if satisfactory crusts are to be produced. Thus pie doughs should be scaled accurately to the size of the pie. This will reduce the amount of trim dough that results from over-scaling, on the one hand, and minimize the need for stretching the rolled doughs that usually results from under-scaling. Trim dough must be salvaged by being remixed into fresh pie doughs, usually those intended for bottom crusts, and normally represents a quality reducing factor; hence the desirability of keeping its quantity to a minimum. The other extreme of underscaling, which produces a rolled dough of a size which inadequately covers either the pan or the filling is equally undesirable since it leads to the tendency of stretching the dough which inevitably causes crust shrinkage on baking. The dusting flour during dough rolling should be held to a minimum. The use of strong flours for this purpose should be avoided. One recommended dusting mixture consists of a blend of 7 parts of pastry flour and 1 part nonfat dry milk solids. The milk solids

are said to offset the possible toughening effect of the dusting flour gluten and promote desirable crust coloration on baking (*218*). Docking should result in large enough vents so that there is no danger of their closing during baking. It is generally desirable to wash the crust with a dilute milk and egg solution, or melted butter, to promote a rich golden crust color. Excessively concentrated wash solutions should be avoided since they tend to impart an artificial glaze to the crust.

Points on Fillings: The handling of fruit for pie fillings also requires certain precautions if a flavorful filling possessing eye appeal is to result. Fresh fruit should be stored in a cool, well ventilated room to prevent mold growth. Under no circumstances should musty or moldy fruit pieces ever be incorporated into the fillings since such fruit will impart a characteristic and highly undesirable flavor to the pie. Fruit which requires washing before use should be washed shortly prior to being processed since wet fruit invites fermentation and more rapid spoilage. It is inadvisable to wash fresh fruit before storing it as this materially reduces its keeping quality. In recent years the quick freezing of fruits harvested at their peak of ripeness has made great technological strides. As a result frozen fruits of good quality are commercially available which constitute excellent ingredients for fillings. Their obvious advantages of uniformity of characteristics, absence of waste, excellent keeping quality, and labor saving need not be detailed at this point. As a rule fruits frozen in smaller containers, as contrasted to full barrels, will show a more uniform quality because of the quicker freeze that is possible with the smaller quantities. Thus it may require six to eight days to freeze fruit solidly in a wooden barrel (*219*) whereas a 30 lb. tin will freeze solidly in two to three days.

Frozen fruits may be thawed either in the conventional manner by keeping the containers at room temperature for the required period or by placing them in tanks of circulating cool water as is done with frozen eggs, or they may be only slightly thawed to loosen them from the container and then heated rapidly with a little water to about 185-195° F. to obtain complete defrosting. The latter procedure is said to preserve the form and flavor of the fruit to a better degree than the former. The defrosted fruit is then drained on sieves or screens, the juice boiled and thickened, and recombined with the fruit. The filling must be cooled as rapidly as possible by means of adequate cooling devices or freezers if it is to retain its brightness and uniform character.

It has been pointed out above that fillings which are excessively warm at the time of use tend to impair crust quality. On the other hand, if fillings are used directly out of the refrigerator, at temperatures below 50° F., difficulties in baking may be encountered. Carlson (*220*) has re-

ported that when using a fruit filling at 40° F. a partially baked crust resulted if average baking times were employed, with the exterior of the crust showing the normal coloration of a well-baked pie, while the inner portion of the crust remained in a raw unbaked state. Best results are obtained if the fillings are brought to room temperature prior to their use.

The tendency of fruit fillings to boil out or to stew in the oven may be due to a variety of causes. Among those whose remedies are obvious are too low an oven temperature which necessitates an excessively long baking time, and using fillings when they are still hot. Fillings which have an insufficient solids content, either in the form of sweetener or fruit, also are apt to boil out prior to adequate baking. Here, of course, the correction lies in so balancing the formula that the solids content of the filling will be at least 30 to 40 percent, not counting the fruit (*221*). Another common fault of fillings is their lack of proper consistency, i.e., the filling is either too thin or too thick. Thin fillings generally result if an inadequate amount of thickener is used, or when incomplete gel formation takes place during boiling. In the latter case, a reduction in the amount of sugar added to the filling during its initial stage of boiling until complete starch gelatinization is obtained, after which the balance of the sweetener may be added, will usually correct the difficulty. Too much sugar in the filling may also lead to a subsequent breakdown of the starch gel, the mass becoming stringy and fluid. On the other hand, if not enough sugar is used and if this deficiency is made up by the use of greater amounts of starch, the filling will become excessively thick and stringy. Other factors responsible for the breakdown of the filling gel are starch hydrolysis by fruit acids which may take place when the fillings are held for too long a period, especially in the absence of refrigeration; and enzyme hydrolysis of the starch that may occur when the fruit has not received sufficient boiling to destroy enzyme activity. Fillings which dry out, shrink and otherwise lack shelf-life usually indicate that not enough sweetener was incorporated, or that too much thickener or the wrong type of thickener was employed. Starch possessing a high content of the amylopectin fraction, such as the waxy maize starch, will frequently stabilize such fillings because of the greater avidity with which it retains moisture. Many of the faults enumerated for fruit fillings also occur in soft pie fillings and very frequently the same remedies will prove effective.

SWEET YEAST DOUGHS

Bakers generally distinguish between three types of sweet dough, namely, straight sweet dough, roll-in sweet dough, and remix sweet dough. The first and last types of dough are used for such yeast-raised

products as coffee cakes, form cakes, sweet rolls, etc., while the roll-in dough has been developed particularly for the Danish pastry type of product.

The following formula of a rather rich straight sweet dough is presented to indicate the approximate relative proportions of ingredients incorporated in a modern sweet dough:

TABLE 132. STRAIGHT SWEET DOUGH

	% based on flour weight
Bread flour	78 } = 100
Cake flour	22 }
Sugar	22
Emulsifying shortening	22
Whole eggs	8.25
Egg yolks	8.25
Dry milk solids	5.5
Water	44
Yeast	8.25
Salt	1.75

It should be understood that this formula represents but one of a practically unlimited number of variations that are possible. If still richer doughs are desired, the proportions of sugar, shortening, eggs and milk require an increase, while if a leaner product is aimed at the proportions of these ingredients must be reduced.

The general procedure for making the straight sweet dough is as follows: The fine granulated sugar, milk solids, shortening, salt and flavoring materials are creamed at low speed until light, which requires approximately 5 minutes. Continuing creaming at medium speed, the eggs and yolks, brought to a temperature of 70-75° F., are gradually added. This should require an additional 5 minutes. Next the yeast is dissolved in part of the water and the total water charge with the yeast is added and mixed slightly. The water should be at a temperature of approximately 80° F. Finally the flour is added and the dough mixed at medium speed until it cleans off the sides of the bowl, which should occur in about 8 minutes. The dough should leave the mixer at about 80° F., the temperature being controlled by proper adjustment of the water temperature.

The formula shown in Table 133 is typical for a roll-in sweet dough. It will be noted that this formula is essentially the same as that for the straight sweet dough except that the shortening has been reduced by one half. This reduction, however, is only apparent, since in addition to the 11 lbs. of shortening used in the dough mix, the dough calls

TABLE 133. ROLL-IN SWEET DOUGH

	% based on flour weight
Bread flour	78 } = 100
Cake flour	22 }
Sugar	22
Shortening	11
Whole eggs	8.25
Yolks	8.25
Dry milk solids	5.5
Water	44
Yeast	8.25
Salt	1.75

for a roll-in mixture which consists, for the above formula, of 9.75 lbs. of butter and 29 lbs. of emulsifying type shortening, or a total of 38.75 lbs. The mixing procedure and sequence of the various ingredients are the same as indicated for the straight sweet dough. The roll-in mixture is prepared 24 hours ahead of time by creaming the fats at low speed until smooth and placing into a refrigerator for conditioning. The mixed dough is scaled immediately into pieces weighing approximately 12 pounds, each piece being rolled to a ¼″ thickness. Next 2 lbs. 5 ozs. of the roll-in mixture is spotted over two-thirds of the dough sheet, the sheet folded three times in such a way that there are alternating layers of dough and fat, and rolled. It is then placed in the refrigerator and given two subsequent three-fold rolls after 30 minute intervals in the refrigerator.

The remix sweet dough is essentially a straight sweet dough which is remixed following fermentation with the incorporation of additional ingredients, which render it richer than the straight sweet dough. This is indicated by the following formula:

TABLE 134. REMIX SWEET DOUGH

To 100 lbs. of straight sweet dough add:	
Bread flour	10 lbs.
Sugar	6¼ "
Butter	6¼ "
Egg Yolks	6¼ "

Compared with a straight sweet dough on a 100 lb. flour basis, a remix sweet dough will contain 22 lbs. more bread flour, 13.75 lbs. more sugar, 13.75 lbs. of butter as against none in the straight sweet dough, and 13.75 lbs. more egg yolks, the final dough weight being 283¼ lbs. as compared with 220 lbs. of straight sweet dough. The procedure is to place the fer-

mented straight dough into the mixer, add the remix ingredients, and mix at medium speed for approximately 5 minutes. The dough should be scaled immediately and given a 10 minute rest before make-up.

All sweet dough should be proofed with very little steam in the proof box. The baking temperature should be kept relatively low, within the approximate range of 365 to 380° F., to prevent undue crust coloration. The baked pieces should be removed from the pans while still warm to avoid sweating.

The following table compares the ranges of ingredients in straight sweet doughs which are generally accepted to fall within the lean, medium, and rich formula categories, respectively (*222*):

TABLE 135. VARIATIONS IN SWEET DOUGH FORMULAS

	Lean %	Medium %	Rich %
Flour	100	100	100
Sugar	10	15	20
Salt	1.75	1.75	1.75
Shortening	10	15	20
Dry Milk Solids	2	4	6
Whole eggs	5	10	20
Yeast	6	8	10
Water	58	52	45

REFRIGERATION OF SWEET DOUGHS

The so-called retarded dough process was introduced into commercial baking about a decade ago and has found widespread acceptance among bakers. Essentially it consists of placing partly fermented doughs under conditions of refrigeration which retard fermentation sufficiently to allow storing of the doughs for a period varying from several hours to a day or two without adverse effects. The process is most extensively used in the production of sweet yeast goods which are more adaptable to such controls than are bread doughs. The success of the dough retarding process depends largely upon the performance of the retarder box or refrigerator. Several types are available, such as multiple-door units with each door leading to an individual refrigerator compartment, single-door walk-in units in which loaded racks of dough may be stored, and combination units possessing features of both types of units. In selecting these refrigerators, the principal consideration should be potential load requirements. Since the optimum conditions to be maintained in the refrigerator call for a temperature of 35° F. and a relative humidity of 85 percent, the capacity of the retarder box should be sufficient to prevent marked deviations from these optimum conditions under

peak loads. Generally, the refrigerator capacity should be such as to provide about 1 cubic foot of air volume for each 4 lbs. of dough (*222*). It is also desirable to have forced air circulation within the box to assure uniformity of temperature.

The primary purpose of refrigeration is to slow fermentation so that doughs can be held up to approximately 36 hours without affecting the quality of the finished products made from them. The extent to which

FIG. 116—View of multiple-door type dough retarder box.

this aim is achieved depends upon four principal factors: (1) richness of dough formula, (2) temperature of mixed dough going to the refrigerator; (3) thickness of dough piece; (4) cooling capacity of the refrigerator. Rich doughs are much more readily retarded than lean doughs and hence may be stored for longer periods without showing excessive aging. The temperature of the mixed dough going into the refrigerator is of importance in that doughs which are too cold will show insufficient maturity, while too warm doughs will age too rapidly. Doughs should therefore reach the refrigerator at their proper temperature and control of retardation should be exercised by means of dough thickness. Thin dough pieces are retarded much more readily than thick dough pieces because of the more rapid and thorough chilling of the thin pieces. Obviously, a box loaded beyond its refrigerating capacity will not retard the dough adequately, so that the matter of cooling capacity of the refrigerator con-

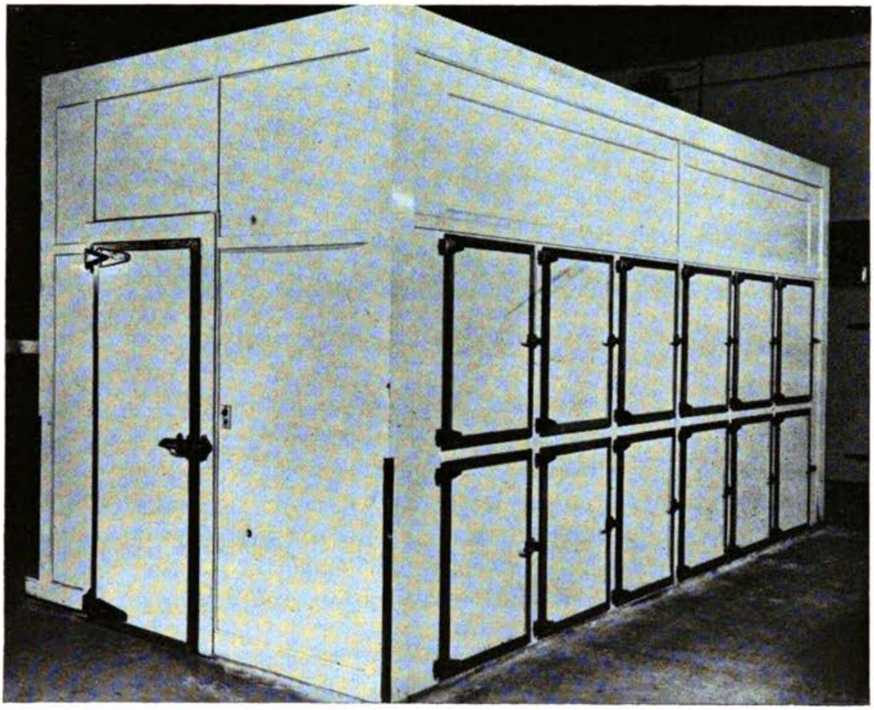


FIG. 117—Dough retarder box combining features of multiple-door and walk-in designs.

stitutes an important control factor. Frey (*222*) has given a detailed account of the principles involved in the retarding of sweet doughs.

FLAVORING OF SWEET DOUGHS

One aspect of vital importance to the production of yeast-raised sweet goods is the type of flavor that is added to these products. Frequently

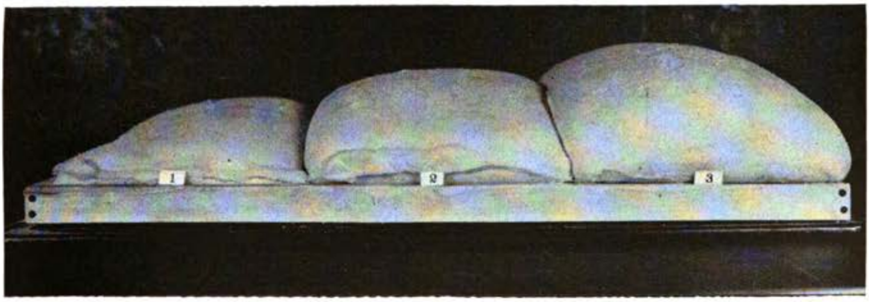


FIG. 118—Effect of richness on fermentation of retarded doughs. Dough 1 was made from rich formula, Dough 2 from medium formula, and Dough 3 from lean formula.

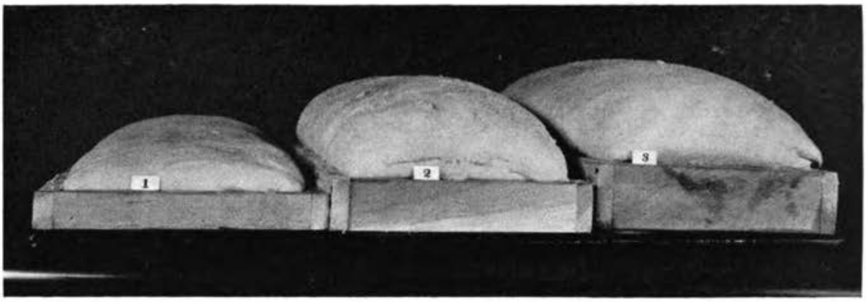


FIG. 119—Effect of thickness of dough piece on fermentation rate of retarded doughs. Thin pieces are more readily retarded than thick dough pieces.

bakers adopt one or two flavors or combinations of flavor which meet with popular acceptance and then keep repeating them in each and every type of sweet dough product they produce without realizing that any flavor, if encountered too frequently, loses its appeal. Thus some bakers use vanilla to excess, while others are partial to mace or lemon. The following five flavor combinations have been found by Montminy (*223*) to be particularly popular in an extensive consumer survey:

TABLE 136. POPULAR FLAVOR COMBINATIONS FOR SWEET DOUGHS

(based on 100 pounds of flour)	
I	
Cardamon (ground)	5½ ozs.
Fresh lemon rind	5½ ozs.
II	
Cardamon (ground)	1½ ozs.
Cinnamon (ground)	1½ ozs.
Vanilla	5½ ozs.
III	
Coriander (ground)	3 ozs.
Cinnamon	1½ ozs.
Vanilla	5½ ozs.
IV	
Coriander (ground)	5 ozs.
Cinnamon	1½ ozs.
Juice and rind of 12 lemons	
V	
Coriander (ground)	3 ozs.
Mace (ground)	1½ ozs.
Vanilla	5½ ozs.

A description of the individual flavors and spices is found on pages 586–595 of this volume.

PART V—BAKERY EQUIPMENT

CHAPTER XXVI

BAKERY EQUIPMENT

One of the most distinguishing characteristics of the American baking plant is its high degree of mechanization. The trend toward replacing manual work by mechanical operation has in many modern plants reached its logical fruition in a completely automatic production process in which manual handling of materials and products has been entirely eliminated. Successful commercial production is today closely dependent on the use of machinery which performs certain operations either more efficiently, more rapidly, or more economically than is possible by human hand. Hence, except for the smaller retail shops which still adhere to a large extent to hand work, all basic operations involved in baking are performed by highly specialized machines. This requires a more thorough mechanical and technical knowledge on the part of the baker than was formerly the case. The efficient and economical operation and maintenance of a wide variety of equipment implies a fundamental understanding of the principles of design of each machine employed in the plant. In the following section an attempt will be made to indicate the major units of bakery equipment, to outline their functions, and to describe briefly their design principles. Obviously, a comprehensive and detailed discussion of all bakery machines in their almost unlimited variations is quite beyond the scope of this work. Such detailed information is obtainable from manufacturers' data sheets and literature which should be consulted whenever additional details are desired.

The type of equipment and the degree of mechanization encountered in a given plant are governed largely by its production capacity. The average small retail shop, for example, in which principal reliance is still placed upon hand work, presents an entirely different picture from the standpoint of equipment than does a modern automatic bread plant in which a minimum number of men turn out five to six thousand loaves of bread per hour.

Bakery equipment in general can be conveniently classified into:

I. Flour handling equipment (dump bins, elevators, storage bins, screw conveyors, sifters, scales, etc.)

II. Dough handling equipment (Mixers, dividers, rounders, moulders, proofers, pans, dough troughs, etc.)

III. Baking equipment (ovens, loaders and unloaders)
IV. Bread handling equipment (depanners, bread coolers, slicers, wrappers, bread conveyors)
V. Miscellaneous equipment (water meters, emulsifiers, refrigerators, steam generators, pan coolers, pan washers, etc.)

I. FLOUR HANDLING EQUIPMENT

Flour is delivered to the bakery either in unit packages of 100 lbs. or in bulk. At the bakery it is then subjected to a period of storage which ranges from one to several weeks. The actual length of storage will depend upon the operator's judgment as to the time required to mature the flour adequately and to bring it to a uniform temperature, on the one hand, and on the available storage capacity, on the other hand. Prior to its use in baking, the flour is frequently given various treatments, such as blending, bolting, aerating, conveying and weighing, each of which requires specialized equipment.

Flour Containers. The most widely used container for the shipment of flour in former years was the wooden barrel which had a standard capacity of 3.75 cubic feet and held an average of 196 to 200 lbs. of flour, depending upon the product's moisture content. With the introduction of cotton and jute bags, the flour barrel slowly passed from the scene until at present its use has been entirely eliminated as a shipping container for flour. Cotton bags represent today the most common flour container, approximately 100 million bags being used annually by the baking industry. The advantages of cloth bags are several. Being standardized to hold 100 lbs. of flour, the bags are convenient to handle and stack; they form a strong container with a minimum of breakage; they provide a certain degree of aeration to the flour which is advantageous from the standpoint of flour aging; finally, they provide adequate sanitary protection to the flour. The disadvantages of the cloth bag include its high initial cost which is only partly offset by its salvage value, and a certain loss of flour caused by seepage through the material and failure to empty the container completely. In recent years a flour container made of strong, multi-walled kraft paper has also found considerable acceptance, its principal advantages being a lower initial cost and the elimination of seepage losses. Still more recently the use of metal bins for handling flour in bulk has come to the fore. The bin in the so-called Tote system is processed from aluminum and has a standard size of $42'' \times 48'' \times 68\frac{5}{8}''$ and a tare weight of 225 pounds. With a content of approximately 74 cu. ft., one such bin has a capacity in excess of 3600 lbs. of flour. It stands on four inch legs which permit the use of pallet trucks or standard form lift trucks for easy handling. After filling at the mill, the bin is sealed air-tight to afford complete sanitary

protection to the flour. It also protects the milled product against fluctuations in its moisture content. In the bakery it may serve as a storage bin, being so designed that several units can be stacked one on top of the other. If desired, the emptying system can be so arranged that the flour is fed directly to the flour-handling equipment for sifting or to the flour hopper above the mixer. In plants where no extensive flour handling equipment is available, the bin itself may serve as the hopper,

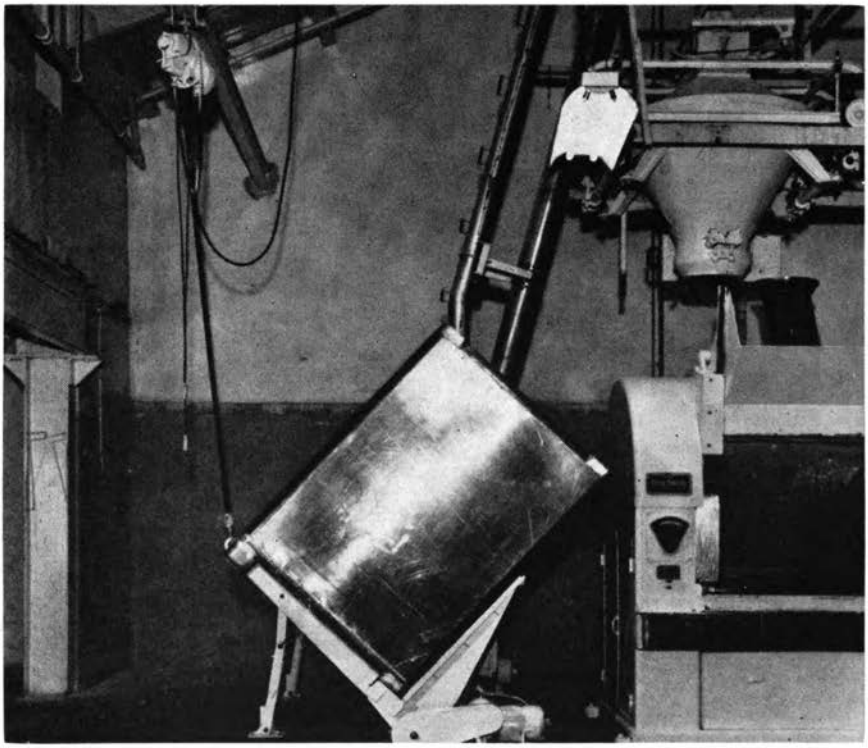


FIG. 120—Tote bin in tilt position for discharge of contents. (*Courtesy Tote Systems.*)

being tilted at a 45° angle by a special tilting device for emptying. Both the filling and emptying operations are designed to completely prevent the formation of flour dust. The empty bins are returned to the mill for refilling. Progress has also been made in developing special truck and railcar tanks of capacities ranging from 30,000 to 140,000 lbs. capacity for the bulk shipment of flour (*228*).

Flour Conveying. Recent years have also seen great improvements in the handling and conveying of flour from the point of delivery at the plant to the point of storage and use. These include the use of pallets

containing loads of up to 24 bags of flour which are handled as single units by means of electric lift trucks. The pallets, which are little more than flat low platforms made either of wood or a suitable lightweight metal, are stacked with the flour load at the mill, transported to the bakery either by railcar or motor truck, and there removed by means of fork trucks which handle one pallet at a time. This method of palletiz-

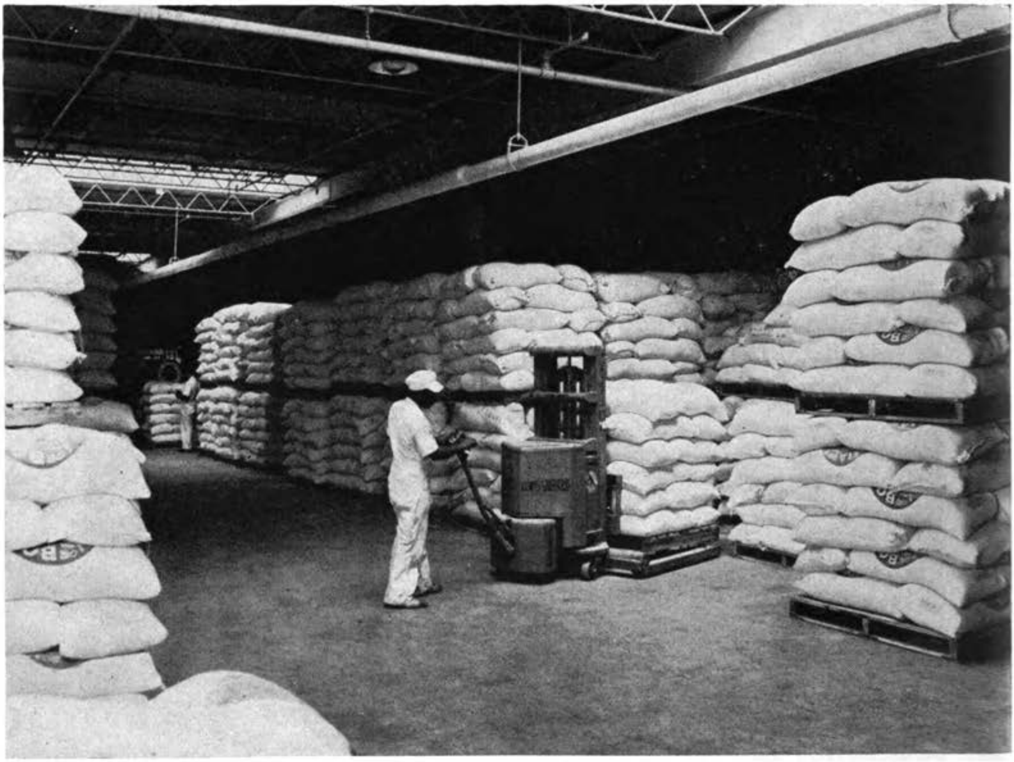


FIG. 121—Palletizing of flour bags makes possible their orderly storage. (*Courtesy Burny Bros. Bakeries.*)

ing sacked material, whether it be flour, sugar, or salt, not only has the advantage of achieving great economies in labor costs, since one man can do the work much more efficiently and rapidly than could otherwise be done by several men required to handle each individual bag, but it also makes possible a far better utilization of storage room since one pallet load can readily be stacked upon another practically up to the ceiling, thereby using overhead space which is normally wasted.

A second improvement in flour movement has been the introduction of pneumatic flour conveying systems. Such a system generally consists

of a dump bin, into which the bagged material is emptied and from which it flows by means of gravity into so-called activators which are little more than pressure chambers. In so-called low pressure systems, it is a pear-shaped vessel with a volume of 30 to 50 cubic feet. When the activator is fully charged with flour, it is sealed and the air-compressor started which builds up the pressure in the activator. Flour movement is initiated through the conveying line leading from the activator to the storage bin by means of an air nozzle installed in the line which directs a powerful air stream up the line, thereby creating a vacuum at the activator outlet. Once flour movement has started, the activator is emptied in a matter of a few minutes. A drop in pressure, indicated on a control gauge, shows when the activator is empty and ready for recharging with a new load of flour. The storage bins receiving the flour are equipped with dust-collectors which exhaust the air and reclaim from it all flour dust. Pneumatic systems at pressures of 40 to 60 lbs. are also used, their principle of operation being essentially the same. The advantages of pneumatic systems are their rapid rate of conveyance of flour from one point to another, both horizontally and vertically, which averages 190 to 250 lbs. of flour per minute; their dust-free operation; the protection they afford against insect infestation, and the savings in labor and space which are inherent in their use. The operational principles of these systems have been described in detail by Otocka (*229*).

While pneumatic systems have been recommended principally for the transfer of flour from the shipping container to the ultimate storage bin, conveyors used within the flour handling system proper are based primarily on mechanical movement of the product. Horizontal movement is most commonly accomplished by means of spiral or helical screw conveyors within a steel housing, while vertical movement utilizes chiefly the bucket elevators, although screw conveyors are also coming into use for this purpose.

Screw conveyors consist essentially of a long central shaft to which is welded an endless spiral or helical ribbon. The shaft is usually mounted on anti-friction type bearings and is driven by an electric motor. As the shaft revolves, the traveling effect imparted to the spiral ribbon pushes the flour in the desired direction. The housing is almost exclusively made of metal, with removable panels to facilitate inspection and cleaning. Horizontal conveyors, depending on whether they are of the overhead or floor type, are generally provided with removable top lids or drop bottom sections to conform to modern sanitation requirements. In most instances the joints of the elevator sections are gasketed to prevent the escape of flour dust on the one hand, and to provide a tight seal against infesting insects on the other.

A conveyor of a different type, but which also moves flour by pushing it through a trough or housing, is the so-called polyplane conveyor. In this conveyor flour movement is provided by a series of paddles spaced approximately 18″ apart and attached to a traveling steel chain. Both the paddles and the chain are encased in a special odorless, tasteless and non-toxic molded rubber to prevent metal to metal contact in the flour area. The rated capacity of this unit is 400 lbs. of flour per minute. One of its principal advantages is its great flexibility which permits dis-

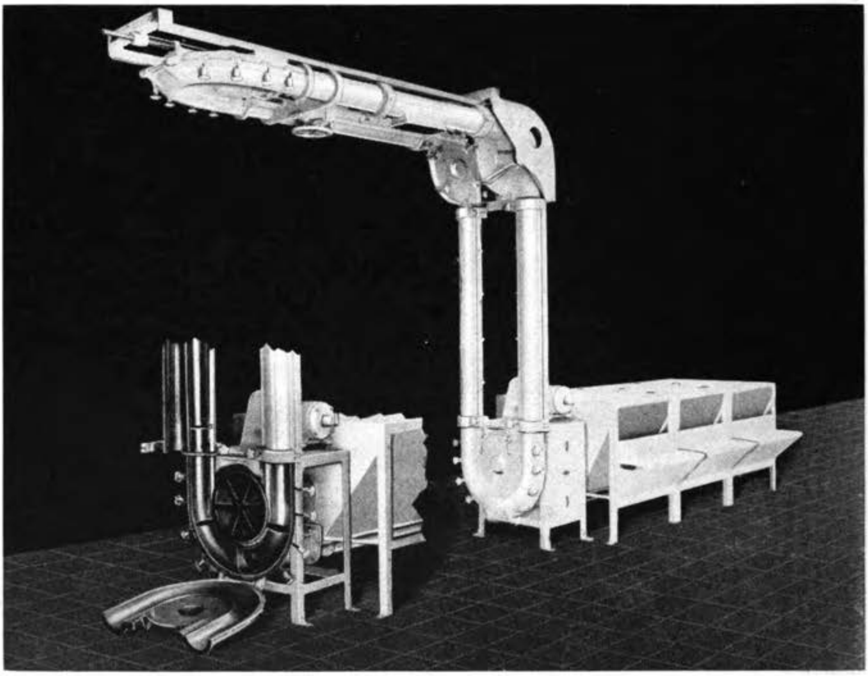


FIG. 122—Polyplane flour conveyor in which flour is moved by a series of paddles. (*Courtesy Read Standard Corp.*)

charge of flour at several points and also allows for continuous operation with flour flowing continually and being controlled by magnetic shut-off gates for returning to the supply storage bins. Another advantage is its ease of cleaning, its design being such that practically every casting and trough section can be removed for cleaning and inspection. By the use of a circular nylon brush all flour may be swept through the entire system while in operation.

Bucket elevators consist of an endless single or double chain to which are attached small steel buckets for conveying the flour. The entire assembly is enclosed in a sheet metal housing of dust-proof construction

and provided with a so-called boot for flour intake and a head for flour discharge. Flour is fed into the leading section of the boot or lower stand of the housing by means of a screw conveyor, is then picked up by the buckets, elevated to the desired height, and dumped into the discharge section of the elevator head from whence it is removed by another screw conveyor. The elevator head is generally designed for centrifugal discharge, with the buckets attached on the outer side of a single chain

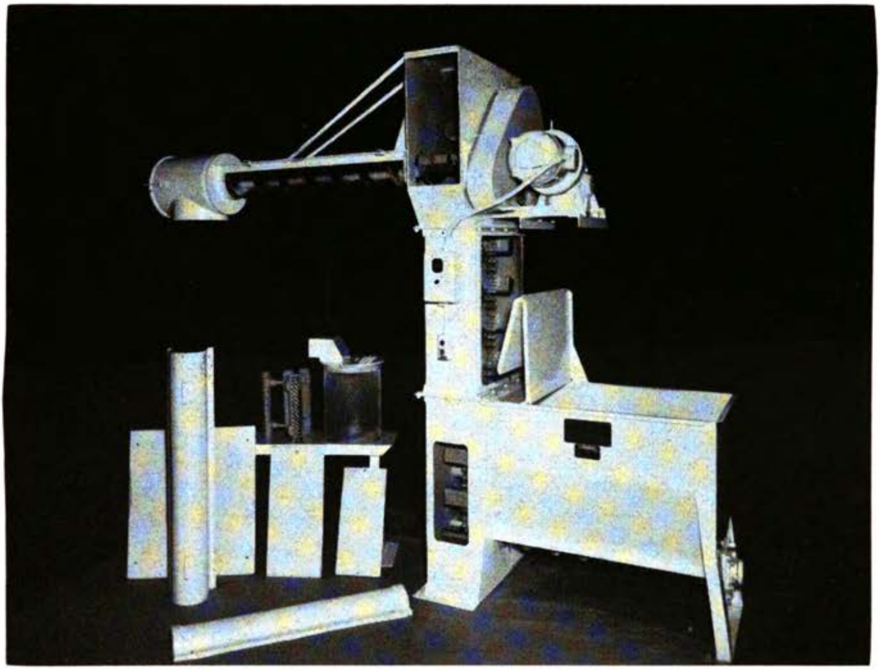


FIG. 123—Small flour handling unit consisting of dump bin, bucket elevator, cross screw conveyor and sifting head. Unit is shown with clean-out doors and panels open. (*Courtesy Peerless Bread Machinery Corp.*)

which travels over a sprocket and dumps the flour into a conveyor. In cases where overhead room is limited or where the conveyor must be built close to the ceiling, the central discharge is used. In this design, which uses considerably less head space, the buckets are fastened between two endless chains and flour dumping occurs at the top center. Bucket elevators are slowly being displaced by screw conveyors in the interest of better sanitation. The basic difficulty in bucket elevators is the unavoidable presence of dead spaces, particularly in the boot, in which flour accumulates and remains undisturbed to provide an ideal breeding medium for infesting insects. Modern design provides for the

easy removal of panels to permit access to all sections of the conveyor. Both screw conveyors and bucket elevators are supplied in standard sizes, such as the 6, 8 and 9 inch models, with rated capacities ranging from a low of 100 lbs. to a high of approximately 600 lbs. of flour delivery per minute.

Dump Bins, Blenders, Storage Bins. The first step in putting flour into production is to dump it from the cotton or paper bag into so-called dump bins, or blenders, from whence it is then transfered by means of screw conveyors to the next unit in the flour handling system. In its simplest form, a dump bin consists of a rectangularly shaped metal cabinet, constructed of sheet steel or other suitable metal and rigidly

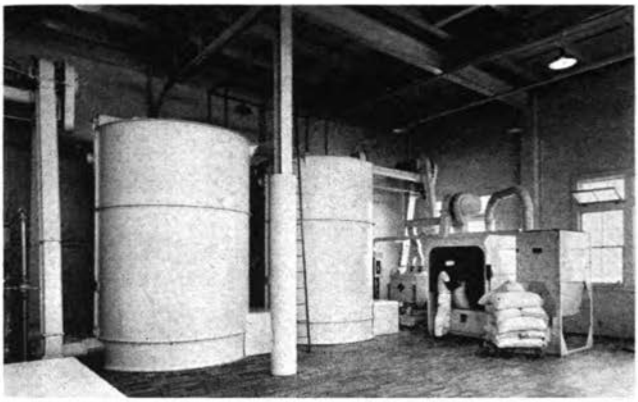


FIG. 124—Modern flour handling system consisting of dump bin with dust collector, conveyors, gyratory sifter, and two cylindrical flour bins of 18,000 lbs. capacity each. (*Courtesy Fuchs Holsum Bakery.*)

braced, with one or both longitudinal side walls sloping toward a discharge spiral conveyor located at the base. It is generally provided with an exterior sack-rest shelf to facilitate dumping. A grid-type guard located above the conveyor to prevent the sack from becoming entangled in the conveyor is a feature of most modern dump bins. Capacities of conventional bin sizes range from 200 to 3,000 lbs. of flour. One of the limitations of a basic dump bin is that it does not as a rule incorporate provisions for the uniform mixing of different flours into blends adapted to specific formula or shop requirements.

This is accomplished by so-called flour blenders which are specially designed metal cabinets containing two or more blending compartments. Each compartment is essentially a dump bin equipped with a variable speed screw conveyor at its base for discharging the flour into a common line at a predetermined rate. By properly adjusting the speed of the

corresponding screw conveyors it is thus possible to obtain blends containing varying proportions of two or more different flours. Conventional blenders of the two bin design provide as a rule for four standard blend ratios, these being 50-50, 25-75, 33-67, and 40-60, although some units have a larger number of conveyor speeds and hence a correspondingly wider range of blend ratios. Units with constant speed screw conveyors are also available. In these the various blending ratios are obtained by changing movable partitions within the compartments, thereby

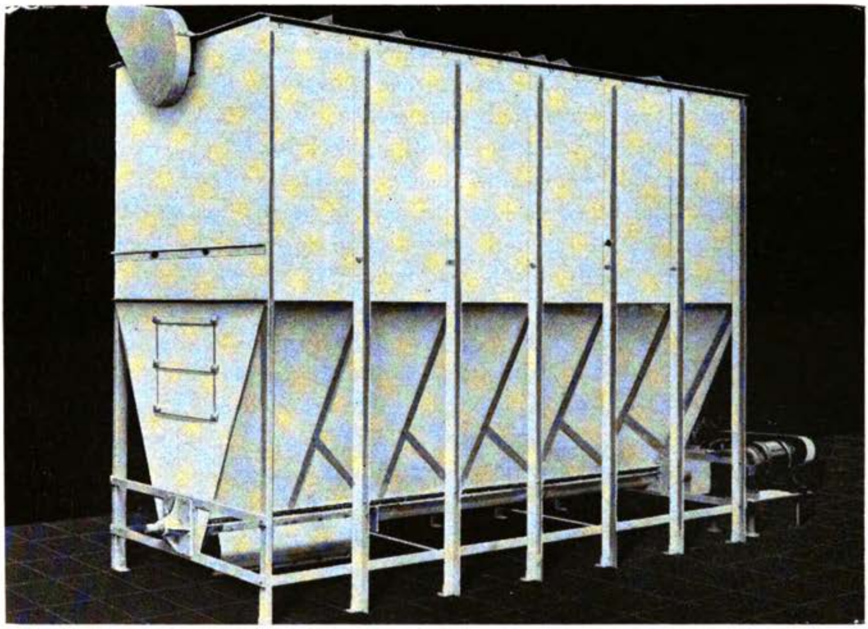


FIG. 125—Flour storage bin of all metal construction. (*Courtesy Read Standard Corp.*)

exposing varying proportions of the different flours to the pick-up action of the screw conveyors. Performance capacities of flour blenders of conventional size fall within the range of 150 to 250 lbs. of flour per minute.

Flour storage bins are now constructed almost exclusively from metal, black iron or stainless steel being most commonly used, with seams either flush riveted or welded. They are frequently designed to fit the requirements of a specific plant and may vary in their capacity from a low of 1,000 lbs. to a high of 20,000 lbs. of flour. They may be round in shape, resembling a silo, or rectangular with straight or tapered sides. Infeed of flour is at the top, while discharge is at the bottom. In a widely used

design, the lower sides of the bin slope steeply toward the discharge conveyor located at the center of the base, thereby preventing flour from adhering to the sides. As a rule, some device in the form of a special agitator is provided to prevent arching of the flour over the discharge conveyor which might lead to uneven flour volume being discharged in a given time period. One type of storage bin, which is cubical in design, is equipped with a multiple-screw conveyor bottom which eliminates the problem of flour arching and also has the advantage of better space utilization. Some bins are equipped with flour gauges which indicate the amount of flour they contain. Filling control devices, which automatically shut off the feed motor when the bin is filled, are also available. The former tendency of providing storage bins with sheeting to improve their appearance has been largely superseded by sanitary considerations which require that all parts be readily accessible for inspection and cleaning, and that all ledges and recesses where flour might lodge and provide a favorable breeding environment to flour pests be eliminated. The development of the circular or silo type bin, with its avoidance of corners, is a logical result of this new trend.

Bag Cleaners. The dump bin or flour blender is frequently equipped with a suction type bag cleaner or dust collector. Basically, these units consist of a suction nozzle which leads to a depositing hopper which, in turn, is connected to an air arrester. A hood, enclosing the dump bin on three sides, confines the flour dust creased by the dumping operation. In practice, the flour sack which has just been emptied is put over the suction nozzle which turns it inside out and imparts to it a whipping action brought about by the air current created by the suction fan. Flour adhering to the bag is thereby dislodged and drawn into the suction fan hopper or depositing hopper where most of it is deposited. The discharged air next goes through an air arrester provided with filters which remove from it the final traces of flour dust, returning the clean air to the room. Modern sack cleaners should remove no less than 98 percent of the flour adhering to bags and their action should be practically instantaneous. Dust collectors operate generally on the same principle as bag cleaners except that they do not have a suction nozzle, the air intake above the bin being much larger. Their use is restricted to plants which receive their flour in paper bags which cannot be conveniently cleaned by the regular bag cleaners.

Flour Sifters. Practically every flour handling unit is equipped with a flour sifter of some type. Sifters may be of the simplest design, consisting of little more than a tubular sieve made of metal and inserted at the discharge end of the screw conveyor, or they may consist of a quite elaborate gyratory system that permits the separation of the flour into

a number of stocks according to particle size. The two principal functions of sifters are to remove extraneous matter, such as lint, string, insect fragments, etc., from the flour, and to subject the flour to thorough aeration. Sifters also contribute toward a more thorough blending of the flour.

Sifters are available in several designs that differ basically in construction and operation. Several distinctive types may be distinguished which have certain features in common, though they may differ in details as developed by different manufacturers. The so-called cone sifters consist

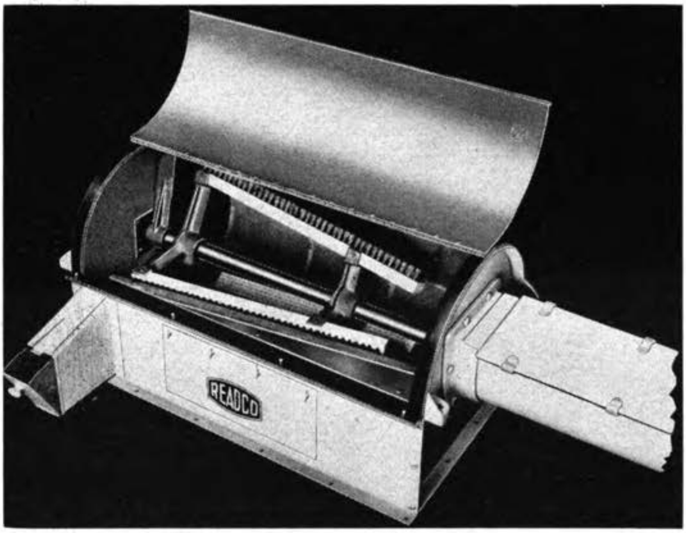


FIG. 126—Cone Sifter in which flour sifting and aeration is effected by revolving brushes. (*Courtesy Read Standard Corp.*)

of a stationary cone-shaped steel mesh screen housed within an appropriately designed metal cabinet. Flour passage through the fine mesh screen is effected by means of heavy bristle brushes adjustably mounted on metal spiders which are actuated by the conveyor shaft. Impurities in the flour, which because of their size fail to pass through the fine mesh, are worked toward the tail end of the screen and forced into a tailing spout. The sifted and aerated flour drops through the bottom of the sifter into the storage bin or the flour hopper above the mixer. One criticism that has been leveled against the brush-type cone sifter is that the brushes working against the screen may also force through some of the more friable impurities that may be present in the flour.

Reel sifter or rotary screen type sifters are still in common use, although they no longer enjoy the universal acceptance, formerly accorded

to them, because of the cleaning problem they present. The reel is usually lined with a fine mesh metal screen and rotates in a direction opposite to that of the brushes mounted within the reel on a metal spider. Flour is fed into the reel at one end and passes through the revolving screen, while contaminating particles that are too large to pass through the fine mesh screen are worked toward the other end of the reel where they pass into a tailing spout.

Various designs of vibrating or gyrating sifters have met with acceptance by bakers and are slowly displacing the other types of flour sifters. While varying in detail depending upon the manufacturer, the most widely used vibrating sifters consist basically of a rectangular

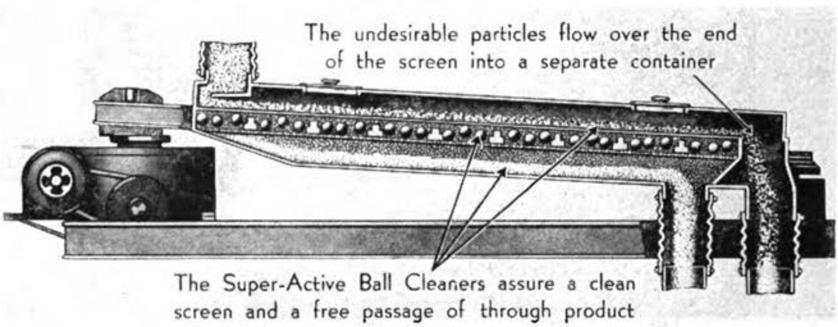


FIG. 127—Gyrating flour sifter which depends upon rebounding balls to produce a vibrating effect to separate flour from extraneous matter. (*Courtesy J. H. Day Co.*)

chassis or base frame, a sieve box, a combination sieve and screen cleaning ball retainer frame, and an actuating mechanism. The base frame is usually made of steel, while the sieve box is fabricated from a light metal. The sieve box is so mounted and attached to the actuating mechanism that a vertically rotating motion is imparted to its head end and a reciprocating motion to its tail end. The cover of the box sieve is provided with one or more inspection ports as well as with an inlet opening which permits the attachment of a flexible, dust-tight rubber sleeve. In addition to the discharge port on the underside of the box, some provision is also made for the removal of tailings, either by means of a special receptacle which must be emptied periodically or by a tailings port for the continuous disposal of the tailings. The sieve frames, mounted within the sieve box, are generally so designed that their screens can be changed so that the fineness of the mesh can be adjusted to specific requirements. The frames are equipped with a cleaning ball retainer section which is divided into cells, each cell containing several balls which under the impetus of the vibrating motion of the box hit

against the underside of the screen and clean it, thereby greatly increasing its sifting capacity. Sifting capacities are, of course, primarily related to the screen surface area and the mesh size, and secondarily to the nature of the flour, its moisture content, grade, etc. A 24 mesh screen measuring 40" wide and 84" long will sift from 200 to 300 lbs. of flour per minute. Most of the gyrating sifters are available in various sizes

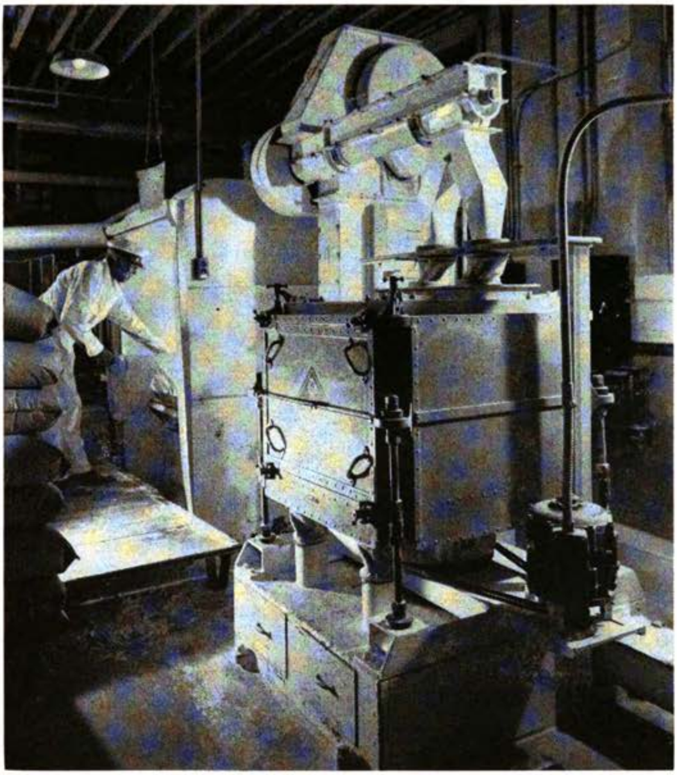


FIG. 128—Low-head gyratory sifter used for rebolting flour in a bakery. Capacity of this unit is 4,600 lbs. per hour. (*Courtesy Allis-Chalmers Mfg. Co.*)

having one to five separations. A gyratory sifter, first used widely in the milling industry, has now also been adopted by bakers. This sifter, of all metal construction, is of a compact square design and hence suitable especially where space is at a premium.

In addition to the high capacity flour sifters that form an integral part of a bakery's flour handling system, there are available many types of small sifters which have been designed especially to handle smaller quantities of flour and which serve frequently as auxiliary equipment in larger plants. Portable floor type sifters have the advantage that they

can be moved from place to place and can be made to discharge the sifted flour directly into the mixing bowls of vertical mixers. Bench mounted types also find extensive applications for handling small batches of flour.

Centrifugal Machines. Recent years have seen the introduction of special centrifugal machines for the control of insect life in all its stages. The so-called Entoletor machine, which measures approximately 3 ft. high and 2 ft. in diameter, consists essentially of a high speed rotor enclosed by a cast steel casing and driven by a directly connected electric motor. The rotor is made up of two steel discs, spaced over one inch apart by specially designed impactors. Flour is fed to the center of the rotor and spun out by centrifugal force into a thinning film as it approaches the perimeter of the rotor. It is discharged in a uniform spray through a hoppered outlet at the bottom. The powerful centrifugal action imparted by the high speed rotor subjects every particle of the flour to severe impact which destroys all eggs and other stages of insect life, but has no effect upon the gluten, starch cells, or baking characteristics of the flour. In the baking plant, the Entoleter unit is generally installed following the sifter in the flour handling system. The machine may also be used as a continuous mixer for dry, free-flowing material.

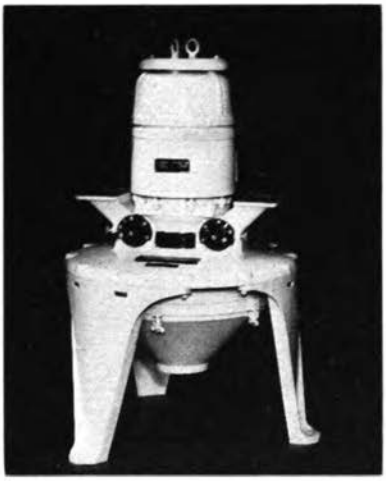


FIG. 129—"Entoleter" infestation destroyer. (*Courtesy Safety Car Heating and Lighting Co.*)

Flour Scales. Modern flour handling systems provide for the automatic weighing of the flour at a point immediately above the dough mixer. This weighing is performed by a special flour scale which, in its most common design, consists of a flour hopper mounted on four-point suspension bearings of case hardened knife-edge steel pivots. After the scale beam is set for the amount of flour desired, the hopper operation is completely automatic, a mercoid switch housed in the scale beam case shutting off the flour supply by means of a cut-off gate as soon as the pre-set weight has been reached. The entire hopper assembly is now fabricated of steel. The hopper itself, which may range in capacity from 200 to 1000 lbs. of flour, is usually conical in shape, with a steeply sloping discharge section to assure complete emptying. Bin type scales are also available for installation where inadequate ceiling height above the

mixer prevents the use of standard hoppers. Both loading and discharge operations are dustless, with a sliding sleeve fitting tightly over the top of the mixer inlet during flour discharge. A common feature of modern hoppers is an air vent which conducts the air displaced by the flour in the mixer to the upper section of the hopper. Weigh hoppers may be either of the stationary or of the trolley type, the difference being chiefly one of the manner of mounting. Stationary hoppers are suspended permanently over a single mixer, whereas the trolley type of hopper is suspended on a trolley and track for use with a battery of mixers. The weighing mechanism is the same with both types.

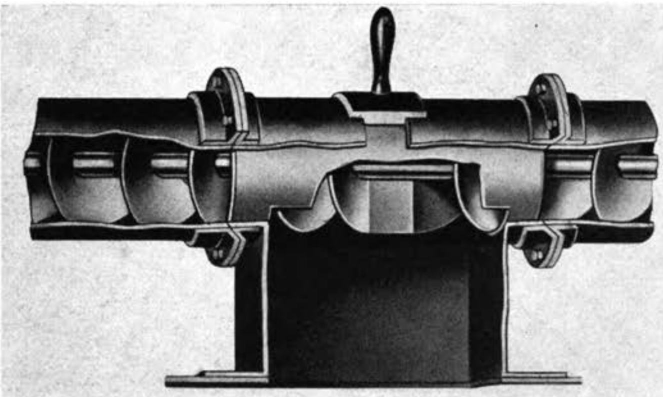


FIG. 130—Flour valve. (*Courtesy J. H. Day Co.*)

Safety Provisions. The American Standards Association has published a safety code for bakery equipment under the sponsorship of the American Society of Bakery Engineers (*230*). This code sets down the requirements pertaining to the design, installation, operation and maintenance of bakery machinery and equipment which will provide reasonable safety for bakery workers.

With regard to flour handling equipment in general, this safety code provides that wherever the various parts of the system run in electrical unity with one another the following safeguards shall apply:

"(a) Each apparatus shall be properly safeguarded by means of disconnecting means for the motor circuits as prescribed by the American Standard National Electrical Code, C1-1946, or any subsequent revision thereof approved by the American Standards Association.

"(b) In addition, wherever a flour-handling system is of such size that the beginning of its operation is far remote from its final delivery end, all electric motors operating each apparatus comprising this system shall

be controlled at each of two points, one located at each remote end, either of which will stop all motors.

"(c) These motor control switches shall be capable of being locked in the open position.

"(d) The control circuits of magnetic controllers shall be so arranged that the opening of any one of several limit switches, which may be on an individual unit, will serve to de-energize all of the motors on that unit."

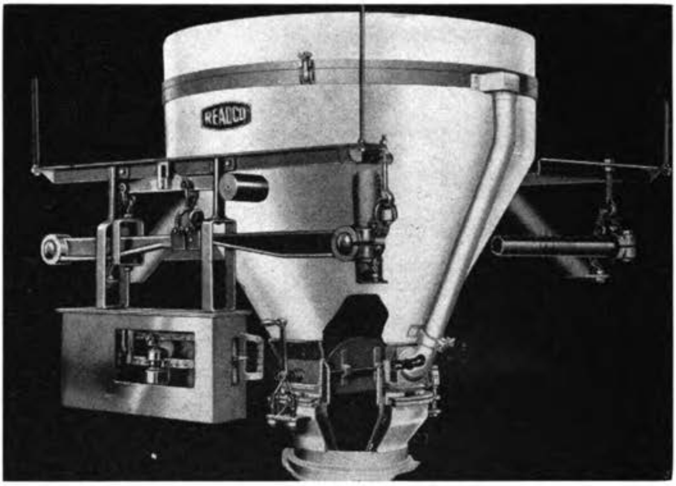


FIG. 131—Stationary flour weigh hopper of the automatic, dustless design. (*Courtesy Read Standard Corp.*)

Other general provisions include the following: All equipment shall be constructed of metal or other nonsplinting material. No removable cover on flour-handling equipment should require a lifting effort of more than 50 lbs. Large systems should be provided with suitable walkways or platforms, maintained in nonslip condition and, where elevated, provided with guard rails and toe boards. Overhead obstructions which are lower than normal standing height should be clearly indicated. All oscillating or vibrating sifters shall be protected with suitable guard rails. All mechanical transmission shafting, gears, and sprocket drives shall be completely guarded, preferably with dust-tight housing. All guards shall be readily removable. All interior or exterior corners should be rounded and all sharp edges avoided. Electric motors should be totally enclosed, with all controllers and switches of dust-tight construction.

With more specific reference to individual units of equipment, the safety code provides essentially the following:

Dump bin and Blender shall have their opening protected by means of bars or grids; hinged dump bin covers shall be provided with latches

to hold the cover in the open position during dumping operation; no separate pits in floors should be required at the point which connects the final discharge to the usual elevator; both units should be equipped with suction-type dust hoods, with a screen provided in the suction nozzle to prevent sacks from being drawn into the rotor of the dust collecting fan; dump bins should be of suitable height to facilitate dumping, with a bag rest step provided whenever the edge of the bin is more than 24 inches above the floor; a control device for stopping the dump bin and blender shall be provided close to the operator.

Flour elevators shall have all removable sections of their casing equipped with suitable clamps for quick removal or equivalent locking devices.

Bolting reels shall have the refuse tailing spouts located at a safe distance from unguarded moving parts and readily accessible.

Storage bins shall be equipped with dust-tight covers which shall be provided with gaskets and locks or latches to keep them closed; the manhole cover shall be provided with a hasp and a lock so that it can be locked in the open position whenever it is necessary to enter the bin; storage bins with sides more than 5 ft. in depth all have standard stationary safety ladders, both inside and outside; large bins should have an offset unloading screw conveyor with an exterior access, removable cover; loading distribution conveyors shall be located in top of bin centrally unhoused; an electric limit switch shall be provided to stop the loading screw if an excess amount of flour is delivered to the bin; an electric interlock between the entrance cover and the motors operating both feed and unloading screws shall be provided and so designed that the motors stop when the cover is in the open position.

Screw conveyors shall have sectional, removable covers, held on with stationary clamps; dead-end conveyors shall be provided with an overflow gate which will operate an electric limit switch to shut down the conveyor before excessive pressure builds up at the dead end.

Sifters shall have dust-tight enclosures, but be readily accessible for interior inspection; all moving parts of vibrating sifters should be well within the outer frame of the apparatus; refuse tailing spouts should be readily accessible and located at a safe distance from unguarded moving parts.

Flour Scales should use only non-shatterable transparent material for the cover over dial scales; trolley type scales shall be equipped with bar handles for moving them; trolley wheels located within 8 ft. 6 in. of floors or platforms shall have full guards on sides and ahead of rotating motion, the scale cut-off shall be totally enclosed; where two or more scales are used on trolley flour scales, interlocks should be provided to prevent opening of the gate unless the hopper is below.

CHAPTER XXVII

DOUGH HANDLING EQUIPMENT

The mixing process performs a number of essential tasks. Among them may be mentioned the thorough mixing of the raw materials, the uniform wetting of the flour to form a homogeneous dough, and the proper development of the resultant dough with the hydration of flour proteins and the mechanical modification of the gluten that accompany this development. To accomplish these tasks efficiently, mixers of different construction and functional principles have been designed. Basically, however, dough mixing machines may be classified into two categories, namely horizontal high and low speed mixers and vertical mixers. Both these types have been standardized to a far-reaching extent in this country in contrast to European equipment which shows considerably greater diversification. Horizontal mixers, operating most efficiently with dough charges in excess of 200 lbs.—their range in capacities is from 120 to 1600 lbs. of dough—are intended primarily for large volume production, while vertical dough mixers are more suitable where smaller dough volumes are encountered. Horizontal mixers are further differentiated into stationary bowl machines, in which the mixing bowl is solidly anchored to the mixer frame and the mixed dough is dumped by lowering the bowl door, and the tilting bowl machines in which the mixing bowl is tilted by a motor-drive during the dumping operation.

Horizontal Mixer. Horizontal mixers are generally high-speed, heavy duty machines, although so-called slow-speed units are also made available to bakers and are usually employed in the production of specialty breads. Basically, horizontal mixers consist of a sturdy frame, either of cast iron or heavy steel channels, in whose upper portion is mounted the mixing bowl, with its agitator powered by a motor located at the base of the unit, the entire assembly being equipped with proper actuating, temperature and time controls. Depending upon the size of the mixer, the motor may range from 5 H.P., usually found in horizontal cake machines, to 50 H.P. in the largest bread dough units. The motor is normally of the two-speed, ball-bearing, high torque type. Power transmission to the agitator shaft is by means of a self-oiling multi-strand roller chain running on cut-tooth sprockets. Agitator speeds, in high speed machines, range from 60/30 to 80/40 rpm. The agitator, whose shaft is mounted in

modern units on packless bearings or glands, is designed to exert a combined mixing, rolling, kneading, and throwing action on the dough.

The mixing bowl is generally constructed of stainless clad steel sheet secured to the two cast ends which are lined also with stainless clad steel. The ends are provided externally with large diameter trunnions which support the bowl. The bowls of most modern high-speed mixers are supplied with jackets to permit the application of artificial cooling. This

FIG. 132—Stationary bowl mixer of 1,600 lbs. capacity. (*Courtesy Baker Perkins Inc.*)

requirement for cooling is imposed by the considerable generation of heat that occurs during mixing and which would lead to an undesirable temperature increase in the dough. The cooling effect is applied by one of three means: (1) direct expansion within the jacket of a refrigerant, such as Freon 12; (2) circulating a low-temperature coolant, such as propylene glycol, through the jacket; and (3) circulating cold water through the jacket. Since cold water circulation is usually found to be inadequate to provide sufficient cooling, the direct expansion or the coolant circulation methods are usually adopted. The jacket, as well as the ends of the bowl, are thoroughly insulated externally with cork board or other suitable insulant to prevent loss of refrigeration on the one hand and troublesome moisture condensation on the other. Because of the importance of temperature control at this stage, mixing bowls are further equipped

with an indicating dial thermometer, whose capillary and bulb project into the back of the mixer bowl a few inches above the bottom which will give a relative temperature reading of the dough coming in contact with the sensing element. If permanent records are desired, a recording potentiometer type pyrometer may be used additionally with its thermocouple mounted in the bottom of the bowl.

One of the primary functions of the mixer, in addition to bringing about a homogeneous dispersion of the dough ingredients, is to mechani-

FIG. 133—High speed dough mixing machine capable of turning out up to 1,600 lbs. of dough per mix. (*Courtesy American Machine & Foundry Co.*)

cally develop the dough gluten by a series of rolling, kneading and stretching actions. This gluten development is accomplished by the agitator whose central shaft transverses the mixing bowl and supports the mixer arms which vary in design with units of different manufacture. Basically, the agitator consists (1) of the drive shaft which usually extends through the mixing bowl, though in some designs it extends only a short distance into the bowl interior; (2) of two spiders of two, three or four arm design mounted onto the shaft at the bowl ends; and (3) of the bars supported by the spider arms. The three armed spiders are usually shaped in the form of a Y, the four armed ones in the form of a cross, while the two armed spiders are frequently formed in the shape of an S. The bars may be either stationary or of the roller type, of even thickness throughout or tapered toward the center, or straight or curved,

all depending on the individual type of mixer. In low speed mixers, the agitator is usually formed in various contours representing modifications of the diamond shape. Where three bar agitators are used, a so-called braker bar is generally installed at the top rear of the bowl whose function it is to absorb the shock of the dough being tossed against the back side of the mixer bowl and to fold the dough. The individual agitator bars perform each a specific function, the pick-up bar carrying the dough mass overhead to the rear of the bowl, while the remaining kneading bars roll the dough forward, kneading and stretching it in the process.

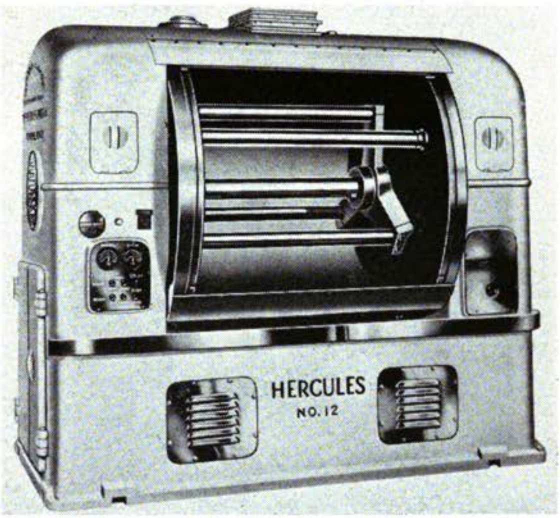


FIG. 134—Tilting bowl high speed dough mixer of 1,200 lbs. capacity. (*Courtesy J. H. Day Co.*)

Auxiliary equipment of mixers includes automatic timers consisting of two-speed electric timing devices that make it possible to set the time for both the low speed and the high speed operation; a dumping mechanism powered by a separate, low horsepower motor; synthetic rubber seals operating under hydraulic pressure to form a watertight seal between the bowl and the bowl canopy or door; and various actuating and stop controls. Push buttons for operating the controls are generally mounted on a common panel at the front of the mixer and are so designed that the operator must use both his hands to control the dumping operation, thereby minimizing the possibility of accidents caused by putting hands into mixers while the mixer arms are revolving.

In baking plants producing bread by the sponge and dough method, a distinction is generally made between sponge mixers and dough mixers, the former being as a rule of a lower rated capacity. Dough mixers are

further differentiated by being equipped with a special sponge chute and by possessing a greater refrigerating capacity.

A mixing action which approaches that produced by human arms is obtained with the so-called Artofex mixer which is of the vertical type and represents one of the very few mixers of European design which have found fairly wide acceptance in American bakeries, especially in plants producing specialty breads and in pie bakeries. The mixer is provided with two agitators which travel through intersecting elliptical paths in a

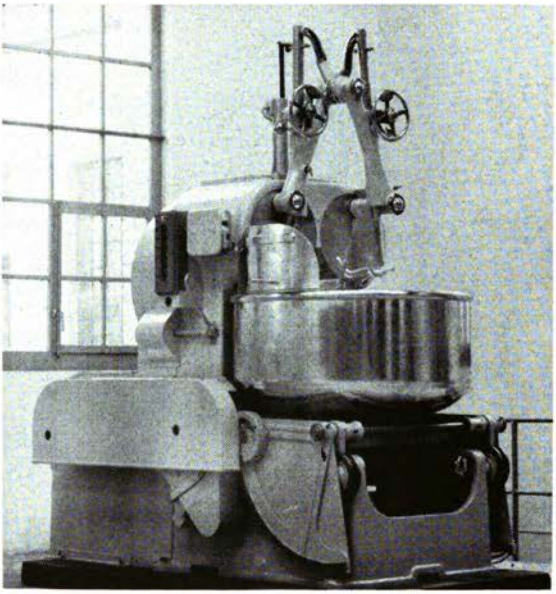


FIG. 135—Three-barrel Artofex Mixer. (*Courtesy Wagner Baking Corp.*)

constantly revolving bowl and impart to the dough a gentle kneading, stretching, lifting and folding action. Since the speed of the mixer is relatively slow, no heating of the dough occurs and the need for refrigeration is obviated. Great flexibility is one of the major characteristics of this mixer as it is equally adaptable to the production of bread doughs as well as of doughs for rolls, sweet goods, biscuits, pies or pretzels.

Vertical Mixers. Vertical mixers are capable of performing a wide variety of mixing operations, from the whipping of light foam batches to the kneading of bread doughs and are, for this reason, particularly suited to the requirements of both small and large baking plants producing a variety of different bakery products. They are constructed along essentially the same line, with their basic design providing for a vertical frame in whose head is mounted the drive mechanism that ac-

tuates the vertical shaft supporting the beater attachments and in whose base is housed the motor which supplies the power for the drive mechanism. In larger units an auxiliary motor is provided to operate the bowl lift.

The mixer frame is made either of cast iron or heavy gauge steel. The mixer motor may range in size from $\frac{1}{3}$ H.P. in the case of small bench type mixers to $7\frac{1}{2}$ H.P. in the largest models whose bowls have a capacity

FIG. 136—Vertical mixer capable of mixing 340 quarts of batter at a time. (*Courtesy American Machine & Foundry Co.*)

in excess of 300 quarts. Motor drive to the gear box is usually through multiple V-belts for quiet operation. Most mixers provide for three or four set beater speeds whose lower limit depends somewhat upon the size of the unit. Small units of, say, 30 quart capacity may have a low mixer speed of 130 rpm and a high speed of 325 rpm as compared to corresponding speeds of 45 rpm and 325 rpm, respectively, for the very largest capacity mixers. Changes in speed are accomplished by means of a transmission which may be of the sliding or the mesh gear type. In mixers equipped with a variable speed drive, any beater speed may be selected within the lower and upper limits of the machine.

Bowls for vertical mixers are made from heavily tinned steel or from stainless steel and are circular containers with round bottoms. They are

provided with handles and lugs, the latter serving to position and firmly lock the bowl in the bowl carrier of the mixer so that the bowl may be safely raised and held in the mixing position. Depending upon the size of the bowl, the lifting and lowering may be done by means of a hand-wheel or it may be performed by a motor drive. As a rule, a bowl truck or dolly is provided for moving the bowl to and from the mixer.

The versatility of vertical mixers is greatly augmented by an auxiliary drive attachment or power take-off which permits the use of a wide va-

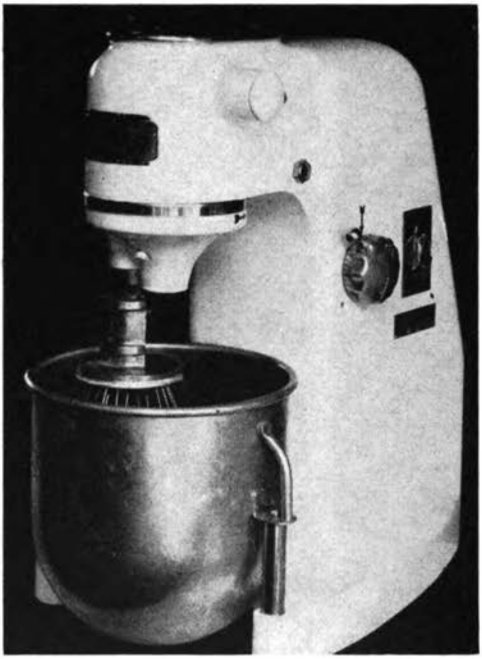


FIG. 137—Vertical mixer. (*Courtesy Century Machine Co.*)

riety of attachments, such as food and meat choppers, vegetable and fruit slicers, juice extractors, etc. Accessory equipment for use with the bowls, such as bowl extension rims, splash covers, colanders, etc., are also usually available with most makes of mixers. A useful supplementary piece of equipment to vertical mixers is the bowl unloader which operates somewhat on the principle of the conventional lift truck in that it will raise a full bowl to the desired height by means of a power lift and tilt the bowl to empty it at a controllable rate. Its use eliminates the need for platforms, hoists, and handlifting.

A basic improvement in vertical mixers came with the introduction of the so-called planetary action of the beater shaft which provides for an

off-center circular motion of the agitator shaft around the bowl, with the beater usually revolving in an opposite direction to its progress. Supplementing this feature with the use of the various types of beaters that are available results in a wide range of mixing actions being obtained.

So-called dough arms or dough hooks are designed to fold, knead and stretch bread and similar doughs, developing the gluten in the process. Because they create little friction, mixing temperatures remain fairly constant and can be readily controlled by regulating the temperature of the ingredient water. The availability of variable speed drives places at the disposal of the operator any dough mixing speed he may desire so that, in this respect at least, the vertical mixer possesses greater versatility than its horizontal counterpart. Creaming or rubbing operations, involving a minimum of kneading or stretching, are performed by a type of beater which is usually flat in form. Some designs are provided with rubber edges for automatic wiping down of the sides of the bowl during mixing or creaming operations. Foam type batters are produced by means of wire whips. There are in addition to these basic kinds of beaters a great many others of varying design which have been developed to perform a variety of special mixing, blending, cutting or aerating operations.

Safety Provisions. Safety provisions for horizontal mixers, as proposed by the American Standards Association (*230*) cover the following essential points:

Mixers with external power application shall have all moving parts, such as belts, chains, gears, sprockets, etc., completely enclosed. Machines with built-in power units shall be similarly protected. Each mixer shall be equipped with an individual motor and control, and a manual switch for shutting off the power during cleaning and servicing. The electrical control station shall be so located that the operator must be in full view of the bowl in its open position and no duplication of the controls other than a stop switch shall be permitted. The power dumping system of the mixer shall operate in such a manner that (*a*) the operator must engage both hands at the controls to keep the agitator in motion under power while the bowl is opened more than one-fifth of its total opening; (*b*) he must engage both hands to start the agitator while the bowl is open more than one-fifth; and (*c*) he has a full view of the bowl opening while he is maintaining the operation of the agitator. Mixers with power dumps shall require the operator to maintain a control contact for obtaining a complete closure of the mixing bowl. The operator should be able to manipulate conveniently all flour-gate operating mechanisms, ingredient openings and water inlets from the normal area of activity without requiring abnormal reaching or improvisations which

might endanger his safety. Every mixer shall be equipped with a full enclosure over the bowl which shall remain closed whenever the agitator is in motion. No loose access doors and covers weighing more than 2 lbs. shall be used on mixers. Overhead doors or covers shall be so counter-balanced as to prevent their accidental closure. Mixers shall be installed on adequate foundations and securely bolted to the floor to prevent dislocation or excessive vibration. Ready access for lubrication at all points shall be provided. Any devices used to return sponges to a mixer shall be so interlocked with the mixer as to prevent injury to the operator. Electrical pilot or control circuits shall have a potential of less than 240 volts. A motor-running over-current protective device shall be provided for each motor, and under-voltage protection in all magnetic controllers. Positive controls to prevent excess pressure in mixer cooling jackets shall be provided. Also all valves and controls regulating the coolant in mixer jackets shall be readily accessible.

With respect to vertical mixers, all provisions stipulated above which are applicable to the vertical machines apply to them also, with the additional requirements that positive means shall be provided to prevent injury to the operator during speed-change manipulation; that bowl locking devices shall be of a positive type; and that devices shall be made available for moving bowls weighing more than 80 lbs. with contents into and out of the mixing position on the machine.

FERMENTATION ROOMS

By far the most critical process in baking is the fermentation of the sponge or dough. The manner in which it is carried out determines not only the ease with which the dough will handle during all subsequent stages of baking, but also—what is more important—the final quality characteristics of the baked bread. Errors committed at this point can no longer be rectified during any subsequent step of baking and will hence detract from the quality of the finished product.

Dough fermentation is influenced by internal as well as external factors. Among the internal factors are included the dough constituents in both their quantitative and qualitative aspects, for a vigorous fermentation obviously requires the presence of an adequate amount of yeast supplied with plentiful fermentable sugars. Yet the rate of fermentation is affected to an almost equal extent by the two basic external factors of temperature and atmospheric humidity. The pronounced accelerating influence of rising temperatures, on the one hand, and the equally marked retarding influence of declining temperatures, on the other hand, on yeast activity in a dough have long been known. More recently, bakers have also come to recognize the important role played by the relative humidity

of the atmosphere in the behavior of fermenting doughs. Early and somewhat primitive attempts to modify adverse atmospheric conditions so as to render them more suitable to the requirements of fermenting doughs have in recent decades resulted in the development of special air-conditioned fermentation rooms that constitute marvels of applied bakery engineering.

The generally recommended temperature and humidity levels for dough fermentation are 80° F. and 75 percent relative humidity. To consistently maintain such an environment requires alternately the application of cooling, heating, humidification and dehumidification processes, depending upon the demands imposed by prevailing seasonal conditions. The artificial creation of the desired climatic conditions is accomplished by means of suitable air conditioning equipment which delivers large amounts of properly humidified air brought to the correct temperature level under automatic controls. This treated air may be supplied either directly to the doughroom, as is the general practice in European baking plants, or it may be used to condition the interior of specially constructed fermentation rooms, as is normally the case in American baking plants.

Most bakers are fully aware of the importance of controlling the temperature of their doughs, having had, as a rule, sufficient opportunity in their practical experience to observe the positive relationship between fermentation rate and temperature. Obviously, the closely scheduled production of uniform products would be quite impossible without accurate control of dough temperatures at all stages from the mixer to the oven. Once the dough leaves the mixer, this control can be achieved only by providing it with an environment maintained at the proper temperature level. While it is quite possible within limits to so adjust the temperature of the dough out of the mixer that the dough will, after an appropriate fermentation period, reach the divider at the desired temperature despite changes in the natural temperature of the dough room, this expedient cannot replace the effectiveness of a fermentation room which is automatically maintained at a predetermined and constant temperature. Seville (*231*) cites the following example of the interrelation between doughroom temperatures and mixed dough temperatures in a series of doughs, each made from 440 lbs. of flour, 1.3 percent yeast, and fermented for 2½ hours in metal troughs.

Doughroom temperature	65°	70°	75°	80°	85°
Dough temp. when mixed	82	81	80	79	78
Dough temp. at divider	82	82	82	82	82

It will be noted that the dough in each instance reaches the divider at the same temperature and at the same stage of development, even

though a considerable variation in doughroom temperature is encountered. This assumes, however, that the doughroom temperature will remain fairly constant during the fermentation and that no other external factors will influence the dough, two conditions which cannot always be relied upon. By using a fermentation room maintained at a constant temperature, the doughs can come from the mixer at the same temperature regardless of seasonal temperature variations.

The nature of atmospheric humidity and its effect upon dough behavior are perhaps less completely understood by bakers. For this reason a very brief review at this point of some of the concepts that relate to the general subject of atmospheric humidity may prove useful.

Air may be defined as a mixture of gases and water vapor in which all the gas components other than water vapor remain practically constant over the temperature ranges normally encountered in nature. The quantity of moisture present in the air, on the other hand, is closely related to the prevailing temperature, the rule being that the higher the temperature of the air the more moisture it can hold. At any given temperature air is capable of holding in suspension a definite maximum amount of moisture per unit volume or weight, when it is said to be saturated. If the temperature of such a saturated air is raised, saturation no longer exists since the air's capacity to hold moisture has increased correspondingly. The ratio of moisture actually held by air to the amount of moisture present in saturated air at the same temperature is known as the relative humidity and is expressed as a percentage. Hence, an expression such as "75 percent relative humidity" indicates that the air, at a given temperature, contains only three-fourths the amount of moisture it would require to reach moisture saturation at that temperature. Now if the temperature of this air were to be raised, its relative humidity would decrease, while if its temperature were to be reduced, its relative humidity would increase, yet its actual moisture content, known as absolute humidity, would remain unchanged. It is thus evident that the relative humidity of the atmosphere is a function of both the absolute moisture content and of temperature. When air containing moisture is cooled below the temperature at which saturation is attained, the moisture which is in excess of the amount required to maintain saturation at the new low temperature condenses out in the form of water droplets. The temperature at which condensation is initiated is termed the dew point. Condensation normally occurs on cool surfaces brought into contact with the warm air.

The relative humidity of the atmosphere is conveniently determined by so-called hygrometers, of which two basic types are in use. The hygroscopic instruments are based on the fact that certain animal and veg-

etable fibers expand and contract with changing humidity conditions. One commonly used material is human hair which possesses marked hygroscopic properties. The scales of these instruments are normally graduated directly in percentage humidity. One drawback of these instruments is that they require periodic checking against a standard hygrometer to determine their accuracy. The wet and dry bulb type of hygrometer depends on the differential temperature of two thermometers, mounted side by side, which results when the bulb of one thermometer is kept dry while that of the second thermometer is kept moist by means of a wick which dips in a small water reservoir. The dry thermometer records the regular air temperature, while the wet bulb thermometer records the temperature as affected by the rate of moisture evaporation from the wick around the bulb. The drier the air, the more rapid will be the evaporation rate and, hence, the greater the cooling effect. As a result the wet bulb thermometer will show a markedly lower temperature. This difference in the temperatures between the dry and wet bulbs is thus related to the relative humidity of the surrounding atmosphere. The relative humidity corresponding to any combination of wet and dry bulb readings may be obtained by consulting a special table. It should be pointed out that constant air movement past the bulbs, at a rate in excess of 10 ft. per second, is required to assure the accuracy of this instrument. This air movement is usually achieved with the aid of a fan.

Seville (*231*) has pointed out that at normal doughmaking temperatures, a relative humidity of 98 percent is required to completely prevent evaporation from the dough. Some moisture will, therefore, be lost at any percent relative humidity below that level, and the moisture loss will be the greater the lower the relative humidity. Moisture evaporation from a dough, if at all pronounced, results in the formation of a surface skin which is dryer than the interior of the dough and which is one of the principal causes of bread faults. Thus, while a relative humidity of 98 percent in the dough room would be ideal from the viewpoint of moisture loss from the fermenting dough, it is actually never aimed at because it gives rise to other difficulties, chief among which are the prevention of moisture condensation and of mold growth within the dough room. Both these problems are avoided at 75 percent relative humidity which, at the same time, is still sufficiently high to prevent troublesome skin formation.

One claim very frequently made for air conditioned dough rooms is that they reduce fermentation losses anywhere from 1.5 and 2 percent down to 0.5 percent by preventing the evaporation of moisture. It is suggested that this 1 to 1.5 percent saving in dough weight is sufficient to pay for the initial cost of the system within a limited time. The va-

lidity of this claim is open to question, however. The first real test of dough consistency is applied at the divider rather than at the mixer, and the baker will automatically adjust his flour absorption to make up any evaporative losses during fermentation and to bring the dough to the divider at the right consistency. Real fermentation losses, i.e., losses in solids due to their conversion by the yeast into gaseous or highly volatile substances are influenced either not at all, or only to a negligible degree,

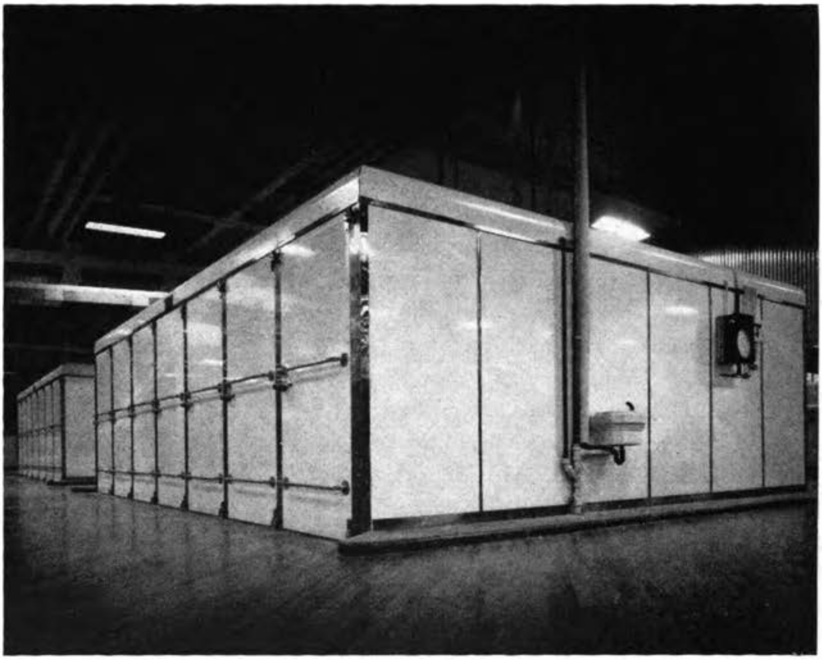


FIG. 138—Fully air conditioned proof box of stainless steel panel construction. Note outside instrument panel. (*Courtesy Union Steel Products Co.*)

by air conditioning. The real value of air conditioning lies in its ability to provide conditions which permit the production of superior goods with far greater consistency than would otherwise be possible. The economic significance of this fact alone should be quite obvious.

Fermentation rooms are available in a variety of designs and constructions, although certain well-proven features have tended to become fairly well standardized with only minor variations in details among units of different manufacture. Thus the majority of fermentation rooms are of sectional or panel construction, utilizing prefabricated parts. The strongly braced frame consists generally of galvanized steel to minimize the problem of corrosion. The walls are metal-lined and provide about

one inch of insulation either in the form of corkboard or some other type of insulant. Doors are secured by double action hinges and are provided with bumpers at trough rim height. Bumpers or guards also afford protection to interior walls against damage by troughs.

An important feature of any fermentation room is the manner in which the conditioned air is distributed. The problem is one of providing a complete air change eight to nine times per hour within the fermentation room without creating strong enough air currents to cause crusting of the

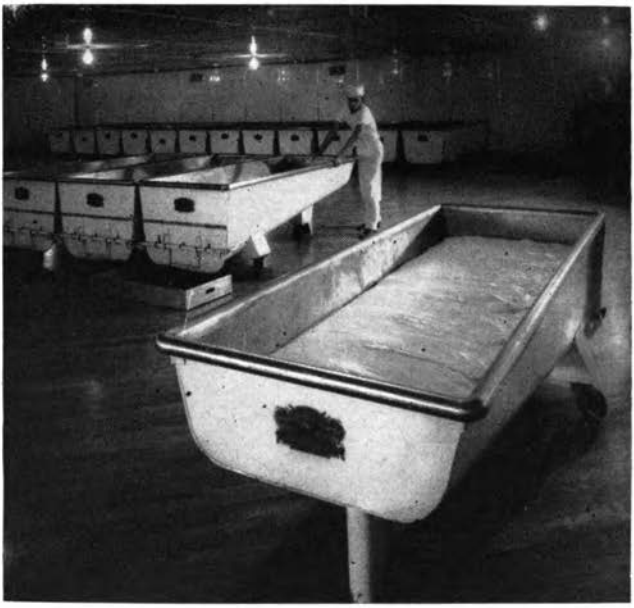


Fig. 139—Interior of fermentation room, showing dough troughs with sloping bottom in foreground. (*Courtesy Helms Bakeries.*)

dough surface. Several solutions to this problem have been worked out, all of which provide for the discharge of the fresh air into the room in such a way that the movement of air in contact with the doughs is kept to a minimum. Circular air diffusers, suspended from the ceiling, are widely applied in this connection. In one system, fresh incoming air is discharged in a horizontal plane through the outer circular louvres of the diffuser with just enough velocity to reach the walls of the room. As the air then settles slowly, it tends to push the old air toward the area beneath the diffuser from whence it is drawn upward and exhausted through the inner concentric louvres of the diffuser. In another system circular air diffusers discharge conditioned air into the room in the same manner as above, but the exhaust air is withdrawn through wall ducts

located near the floor and so distributed that correct air distribution is assured. In still another system the freshly conditioned air is admitted into the room by means of a series of ducts located at nearly floor level along opposite walls and moves toward the center of the room and upward toward the exhaust duct running along the center of the ceiling. All three of these air distribution systems successfully avoid harmful draughts, yet bring about the necessary change of air within the fermentation room.

The actual conditioning of the air takes place in a self-contained unit which operates automatically by means of sensitive control instruments.

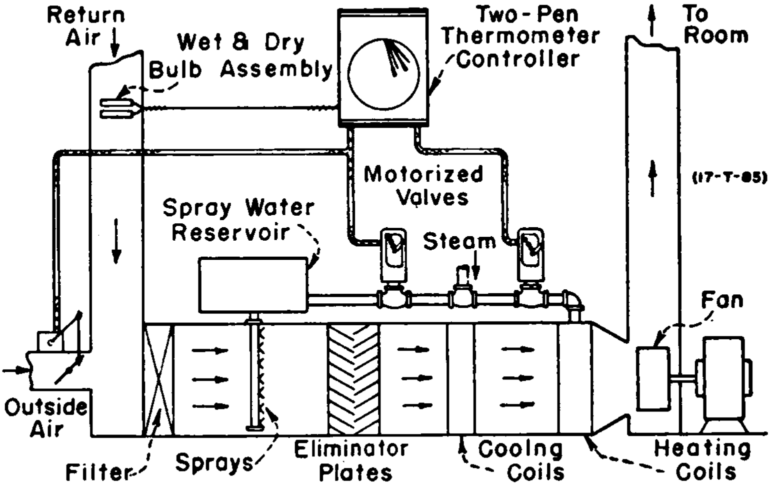


FIG. 140—Schematic diagram of an air conditioning system for a fermentation room. (*Courtesy Minneapolis-Honeywell Regulator Co.*)

A complete conditioning unit will consist of cooling and heating coils or radiators, a humidifying system, water sprays, eliminators and fans, together with the necessary motors, pumps, valves, fittings, control instruments, etc. The cooling and heating coils are brought into action by controls actuated by the wet and dry bulb thermostats, respectively. The cooling coil performs a multiple function. It cools incoming air if its temperature is too high for dough room requirements. At the same time it aids in the control of the relative humidity by removing moisture through condensation if the natural humidity of the atmosphere is too high, or by increasing the relative humidity of the cooled air by the mere act of cooling. The humidifier supplies moisture to the air in the form of steam should the wet bulb thermometer indicate a need for additional humidification. The principal function of the battery of water sprays is to cleanse the incoming air of dust, molds and bacteria. The cleaned

air next passes through so-called eliminators in which minute water droplets entrained in the moving air are deposited so that no free moisture finds access to the distributing ducts. The steam radiator forms the final treating section of the unit and maintains the air at the proper temperature, the flow of steam into the radiator being regulated by a valve controlled by the dry-bulb thermostat. Air movement through the distribution ducts is obtained by means of a multiple vane fan whose size and speed are adjusted to provide the correct amount of air being furnished to the fermentation room. Because of the moisture conditions prevailing within the conditioning unit, rust-resistant metals are used throughout in its construction.

In addition to conventional dough rooms, the so-called cabinet system of sponge and dough fermentation has gained acceptance, especially in smaller baking plants. In this system, the individual dough troughs are either provided with deep insulated covers made of metal or wood which enclose the entire trough, or the troughs are placed into stationary cabinets just large enough to accommodate a trough with sufficient space above to allow for the expanding sponge. Under these conditions the relative humidity of the atmosphere surrounding the sponge soon reaches a constant limiting value, while the temperature is also protected against marked fluctuations. Proponents of this system claim that the results obtained with fermentation cabinets are at least as good, if not better, than those obtainable with controlled fermentation rooms, while their initial cost is much lower and their subsequent upkeep involves far less effort.

MAKE-UP EQUIPMENT

After the dough has been properly matured in the fermentation room, it is ready for scaling into loaf units of accurate weight and the subsequent treatment required to prepare it for the oven. The standard equipment involved at this stage of processing include, in sequential order, (1) the divider which scales the bulk dough into small units of predetermined weight and which is subject to control by volumetric adjustments to equate for changes in the density of the dough in the course of the dividing operation; (2) the rounder whose task it is to impart a spherical shape to the unsymmetrical dough pieces emerging from the divider and, at the same time, seal their raw cut surfaces with a fine skin to prevent excessive bleeding off of evolving carbon dioxide gas; (3) the intermediate or overhead proofer whose function it is to give the rounded dough pieces a brief rest so that they may recover from the punishment they sustained during scaling and rounding; and (4) the moulder, which removes much of the gas from the rounded dough pieces and shapes them

into their final elongated loaf form. The made-up doughs, placed into pans, are then subjected to a vigorous final fermentation under near optimum temperature and humidity conditions maintained in a final proofer or steam box after which, having risen to the proper height in the pans, they are ready for baking in the oven.

DOUGH DIVIDERS

Dough dividers are designed to automatically and accurately divide the fermented dough into pieces of pre-set volume for making into loaves. Machine dividing is based primarily on dough volume instead of on dough weight as is the case with hand scaling. The actual weight of a dough piece of a given size is a function of dough density, which in turn is variably influenced by such factors as time, temperature, yeast activity, etc. It is therefore evident that the volume of the dough pieces produced by the divider will undergo a slight variation as adjustments are made to make up for a decrease in density to maintain a uniform weight. Good practice calls for dividing within as short a time period as possible and with a minimum increase in dough temperature so as to yield dough pieces of the same volume and weight. This dual objective is best accomplished by a proper control of the weight of the original dough batch rather than by increasing the speed of the machine beyond safe limits. The highly viscous nature of the dough imposes a limit on the speed at which a divider may be properly operated. Most machines have a maximum speed rating of 20 strokes per minute, or one stroke every three seconds. Not all types of dough are suitable for dividing at that speed and it is better practice to operate dividers at speeds of 15 to 16 strokes per minute. At these decreased speeds the dangers of incompletely filled dough pockets or severe dough punishment are largely avoided. If increased production is required, the recommendation is to use dividers with a greater number of pockets. Standard machines are equipped with one to eight pockets, i.e., one to eight pieces of dough are scaled off with each stroke of the ram or plunger. Operating at a maximum speed of 20 strokes per minute, an 8-pocket divider will thus deliver 9,600 dough pieces per hour.

Basically, a dough divider consists of a sturdy frame which houses in its lower part the driving mechanism and other working parts, such as the various shafts, levers and rods, and supports in its upper section the scaling head. This is comprised of the dough hopper which receives the bulk dough from the dough trough. The hopper feeds directly into the dough chamber or compression chamber immediately beneath into which the dough flows by gravity. A dough knife, traveling horizontally along the base of the dough hopper, cuts the dough filling the dough chamber

from the bulk dough. The severed dough is next forced into the series of dough pockets of pre-set volume by means of a ram which applies an even pressure to the dough. In some dividers the pockets form part of a movable division box which travels downward after being filled with dough, thereby shearing off the dough pieces as the pockets move past the shear edge of the dough chamber. Or the pockets may be housed in a cylindrical division box with one segment of the cylinder cut off from

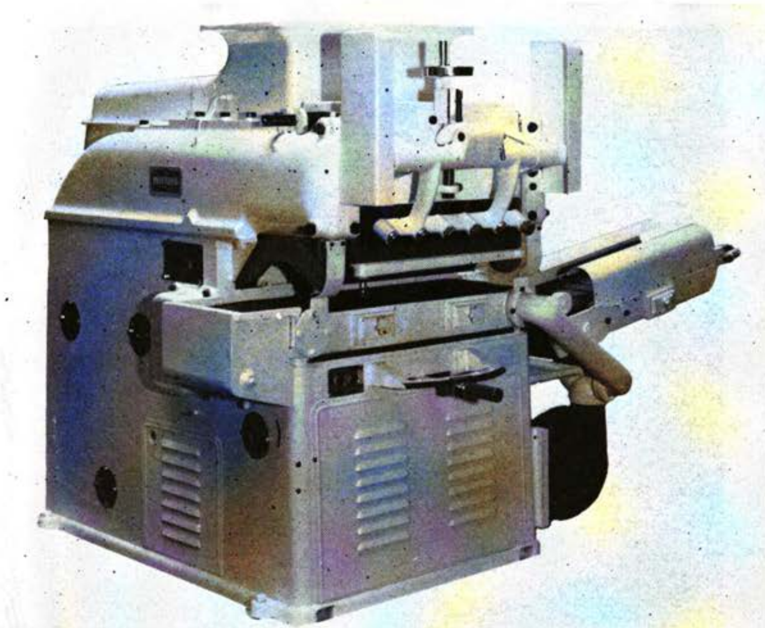


FIG. 141—Six-pocket dough divider with air drying conveyor. (*Courtesy Baker Perkins Inc.*)

one side and serving as a shear edge as the cylinder rotates. The individual dough pieces are then ejected from the pockets by means of pistons supported on an ejector lever and dropped onto a conveyor immediately below the division box which conveys them to the rounder.

An important feature of dough dividers is their lubricating system. Freshly cut dough is extremely sticky and will adhere to any metal surface with which it comes into contact unless that surface is specially treated to reduce sticking. In practice this is accomplished by spreading a fine film of divider oil, consisting usually of a clear, tasteless and odorless mineral oil, over all surfaces which come into contact with the dough. Oiling systems may be either of the gravity type, in which the oil is fed by means of tubes to the critical areas from an elevated reservoir, the

surplus oil being drained into a container at a lower level; or they may be of a positive type in which the oil is pumped to the various parts of the dividing mechanism at a rate sufficient to meet lubrication requirements.

Additional features of dividers include devices for adjusting the scaling volume of the dough pieces, controls for regulating the operating speed, provisions for dusting the dough pieces, devices for centering dough pieces on the conveyor belt, start and stop push buttons, and others.

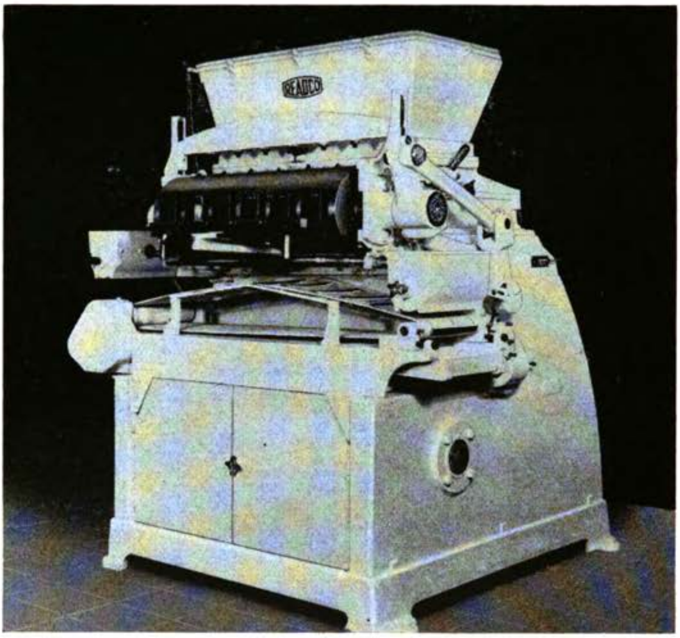


FIG. 142—A six-pocket dough divider. (*Courtesy Read Standard Corp.*)

While in properly designed dividers all moving parts are machined to close tolerances to prevent leakage of dough between the parts and the formation of hard dough films, it is nevertheless recommended that great care be exercised in the cleaning of dividers. Cleaning is preferably carried out at the end of each day's run. If the machine is to stand idle for a short period only, the suggested procedure is to clean out all excess dough and pour in one half pint of divider oil. The machine is then operated just long enough to obtain thorough distribution of the oil over all critical surfaces and thereby prevent damaging hardening of the dough film. If the machine is to be cleaned for the day, the dough knife, ram and pistons should be removed from the machine, washed thoroughly in a solution of soda, rinsed, dried and wiped with a soft cloth

dipped in divider oil. At the same time, the dough hopper, dough chamber and dough pockets should receive equally thorough cleaning. The scaling head should then be re-assembled, one half pint of divider oil poured in and the machine operated through two or three cycles to obtain thorough oil distribution. If scraping is required, a hardwood scraper only should be used to avoid scoring of metal surfaces.

Safety provisions. The following major safety provisions for dividers have been proposed by the American Standards Association (*230*):

Guards shall be provided at all pinch points and shear points from reciprocating or rotating parts to eliminate hazards to the operator's hands and fingers. Front guards shall be so arranged that the weight of dough pieces can be adjusted without removing the guard. All moving parts shall have a complete cover. The rear cover shall be provided with a limit switch so that the machine cannot be operated when this cover is open. The cover shall be hinged so that it cannot be completely removed and it shall be provided with a catch or brace so designed to prevent accidental release. The oil holes in the knife at the back of the divider shall be small enough to make it impossible for an employee to insert his finger into them. A saddle guard or other protective device shall be provided for any elongated hole in the knife actuating arm. Dividers shall be equipped with mechanical overload release devices such as shear pins.

LOAF ROUNDERS

The function of the rounding machine is to automatically round or ball up the divided dough pieces, imparting to them a thin, smooth and dense skin in the process. Although rounders vary considerably in design, their basic principle of operation is essentially the same: A revolving member forces the dough piece to travel upwards in a spiral or rounding trough, causing it to turn in such a way that all parts of its surface are exposed to the revolving surface so that the dough piece receives a uniform rounding. The revolving surface may be shaped in the form of a bowl or cone, an umbrella, or a drum. Each design has proved popular and has met with widespread acceptance.

The conical or bowl type rounder consists essentially of a revolving bowl on whose inner surface a stationary spiral forms a dough race. The spiral extends from the lower section of the bowl to its upper rim. The dough pieces are fed to the rounder through a special intake hopper through which they drop to the lower end of the spiral where they are immediately engaged by the revolving cone surface. They then travel upward in the spiral and are discharged to the intermediate proofer. The umbrella or inverted cone type rounder consists of a spindle-supported

revolving cone table. A stationary rounding trough or dough race, supported against its outer surface, spirals upward from its outer edge toward the center and supplies the rounding action to the dough piece as it travels upward toward the discharge chute. In the drum rounder the revolving bowl has nearly vertical sides against which the dough race is supported. Its principal advantage is that it occupies a very limited amount of floor space and can usually be located closer to the divider than the two other types.

FIG. 143—Cone-type rounder. (*Courtesy Century Machine Co.*)

Differences in rounders are not limited to their general shape, but involve also many operating features. Thus in the conical rounders the initial rate of travel of the dough piece is slow and increases progressively as the dough piece reaches the end of the spiral, whereas in the inverted cone rounder the reverse is true, the dough piece being taken up at high speed which is then reduced as the dough travels toward the discharge point. While the first mode of action offers perhaps a more positive means for preventing the formation of doubles, the latter duplicates more closely the action of hand rounding. Different designs of rounders differ markedly in the manner in which they achieve certain aims, such as keeping the revolving surface clean, preventing the formation of dough pills and lumps, exerting a positive revolving force on the dough piece, producing a kneading action on the dough, applying a con-

trolled amount of dusting flour to prevent dough sticking, and other features. In some rounders the revolving surface is finely grooved, whereas in others it is smooth. Some rounders use the conventional type of duster, others utilize wax to prevent sticking, while still others have resorted to compressed air to attain the same end. Opinions differ widely as to which method is the most effective.

Maintenance of the rounder is chiefly a matter of keeping the rounding surfaces clean and the drive mechanism lubricated in accordance with

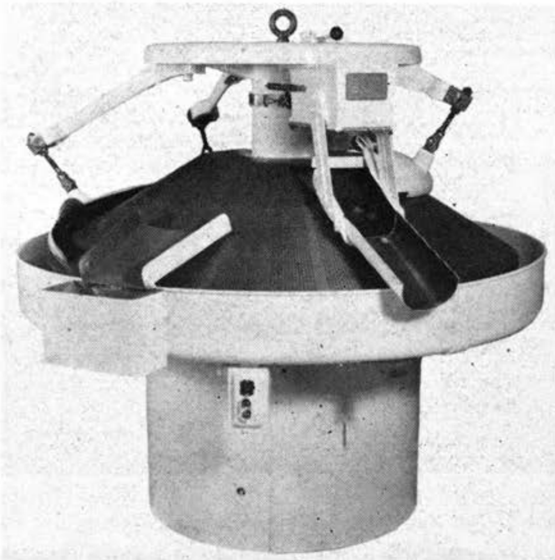


FIG. 144—Inverted cone-type-rounder. (*Courtesy Baker Perkins Inc.*)

the manufacturers' instructions. The rounder should be thoroughly cleaned of all dough traces at the end of each day's run and before the dough has had a chance to harden. If it should prove necessary to scrape dough from the cone or bowl surface, special wooden scrapers should be used since metal scrapers may score the surface.

INTERMEDIATE PROOFERS

The dough pieces, as delivered by the rounder, are rather dense and heavy, having lost much of their gas during the divider operation. To facilitate the next major physical operation, which is to mould the dough pieces into their final loaf shapes, they must be given a brief rest during which fermentation can proceed undisturbed under favorable conditions. At the end of this intermediate proof the dough pieces should have aerated to approximately twice their original size and should have acquired

a highly pliable and extensible character. Depending upon the consistency and age of the dough as it reaches the intermediate proofer, as well as the proofing temperature, this development should be attained in a maximum time period of 10 to 15 minutes. Proofing temperature should be somewhat higher than normally maintained in the dough room, a level of about 80° to 85° F. being generally considered most acceptable. The relative humidity should be within the range of 70 to 73 percent to prevent crust formation on the individual dough pieces.

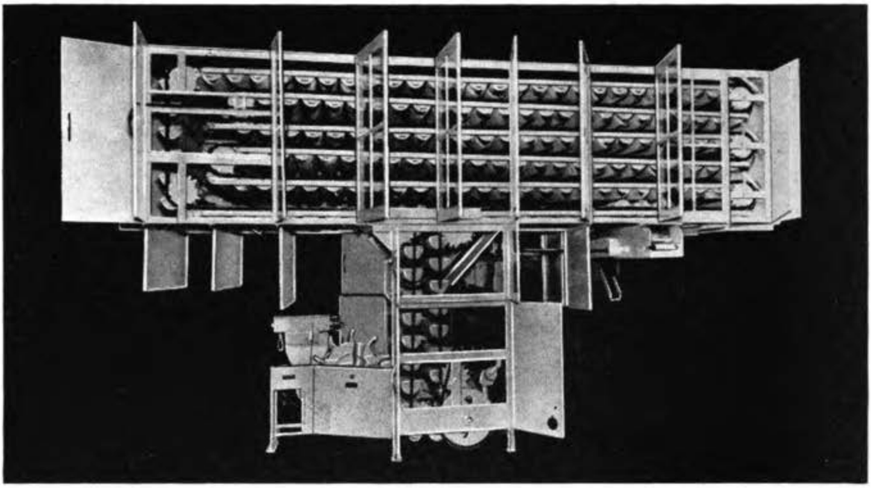


FIG. 145—Intermediate overhead proofer designed to facilitate easy accessibility for sanitation control. (*Courtesy Union Machinery Co.*)

Automatic intermediate proofers consist essentially of a slow-moving endless belt or conveyor supporting either trays, buckets or loops which serve as dough carriers, the entire assembly being enclosed in a housing. The over-all design may be such as to impart an "L" or a "T" shape to the proofer, with the horizontal portion being elevated against the room ceiling. Floor models of the conventional box type, for installation in areas of limited overhead space, are also available. Frame construction is generally of structural steel, and the enclosure consists largely of sheet metal, with the sides being provided with hinged sash. Ready accessibility to all parts of the unit is being stressed in modern designs, with lift-off covers and access doors constituting standard features.

Among the principal distinguishing features of different intermediate proofers is the type of carrier employed to convey the dough through the proofing cycle. From a mechanical standpoint the belt type is the simplest, having the least number of moving parts. However, it requires more supervision than the other types during operation, for unless the

belt tension is kept properly adjusted there exists the possibility of the dough pieces jamming or being brought into contact with each other, producing "doubles." Tray type proofers are of two kinds. In one the trays are made of wood, being machined into shallow troughs supported by two parallel steel roller chains operating over cast iron sprockets and steel angle tracks. In the other, the trays are built with cast ends and steel tie-rods supporting a canvas dough rest. In the third type of proofer, the dough pieces are deposited into individual semi-circular tray compartments. Being constructed of perforated metal, these compartments or cups eliminate some of the sanitary problems associated with the use of canvas. In a fourth type of proofer, the dough pieces are deposited onto flat trays over which arch so-called loops made of canvas which provide a protective cover for the doughs during most of the proofing cycle. The bucket type conveyor consists of a series of buckets attached to a chain, each bucket taking a single dough piece.

Dough balls delivered by the rounder are first deposited onto the belt conveyor of the loading mechanism which, variously designed with different makes of proofers, operates to drop them in turn onto the proofer tray that has moved into position. Trays come in various widths, accommodating two to six dough pieces, equally spaced apart. The doughs are then slowly conveyed through the proofer. If the proofer is of the flat tray type, the doughs are usually transferred to a second tray at the mid-point of proofing, the transfer being accomplished in such a way that the dough pieces are inverted in the process. The purpose of this transfer is to reduce the tendency of the dough pieces to adhere to the bottom of the tray and at the same time also to prevent the development of a sticky side on the bottom and a dry crust on the top side of the proofing dough piece. In the case of the deep cup type proofer, in which the direction of travel is vertical rather than horizontal, such a transfer is obviated since the cups make a full turn as the conveyor reverses its travel, so that the dough pieces are rolled back and forth within their carrier in the course of proofing. A similar effect is obtained with the loop proofer. After completing their travel through the proofer, the dough pieces are discharged from the trays or cups into a timing device which automatically releases them, properly spaced, onto the discharge belt feeding to the moulder sheeting rolls.

Since the proofer constitutes a link between the divider and the moulder, the necessity of synchronizing its rate of travel with the speeds of both of the other units is obvious. The use of a variable speed drive or transmission, which permits the regulating of the proof time within close limits, is therefore an indispensible requirement.

While in the majority of cases no effort is made to air-condition the

proofer, it is possible to maintain its humidity at the desired level by connecting it with the air-conditioning unit supplying the dough room, or by injecting a small amount of saturated steam into the proofer at the intake point. Proofer design should be such that interior drafts are avoided.

THE MOULDER

The function of the moulder is to sheet, curl and seal the individual dough pieces delivered by the intermediate proofer, imparting to them their final loaf shape and at the same time subject them to a manipulation that will serve to improve the grain and texture of the finished bread. Moulding constitutes a critical stage in dough make-up, for if improperly carried out it introduces a number of faults, such as streaks, cores, coarse grain and holes, into the bread crumb. Since each type of dough will react differently at the moulding stage, accurate moulder adjustment to requirements imposed by the nature of the dough as well as the kind of bread aimed at becomes a necessity.

The basic design of moulders incorporates a series of more or less closely spaced rolls between which the dough is flattened into a thin sheet. In conventional moulders, this sheeting process is generally accomplished by three sets of rolls which include a pair of pre-sheeting rolls and a pair each of top and bottom rolls, each pair being set more closely together than the preceding one. Frequently there is also a so-called flattening roll at the end of the infeed belt to give the dough ball a preliminary flattening and thereby facilitate its being engaged by the pre-sheeting rolls. Each roll is equipped with a scraper blade whose function it is to keep the roll clean of adhering dough. The adjustment of these scrapers against the rolls is of considerable importance since too tight an adjustment will lead to over-heating of the rolls, whereas too loose an adjustment will fail to effect adequate cleaning. Recently, the use of a plastic coating on the rolls has gained considerable acceptance. This material, offered on the market under the trade-name of "teflon," is an exceptionally inert, tough waxy solid, highly resistant to abrasion and possessing a marked non-adhesive character. Since dough will not stick to it under ordinary conditions, its use as a roller coating eliminates the need for scraper blades and at the same time greatly reduces the requirements for dusting flour.

One of the problems of conventional sheeting is that as the dough passes through the various sets of rolls, there is a tendency to have the moisture of the dough piece squeezed toward the tail-end of the dough sheet. Since normally the lead edge of the dough sheet forms the center of the moulded dough loaf, there is an uneven distribution of moisture

in the dough piece during the initial stages of the final proof, with the dry portion of the dough forming the core of the loaf. In an attempt to correct this undesirable condition, a method of reverse sheeting has been developed. In this method the dough, after having passed through the first two sets of sheeting rolls, is turned end for end, and passed through the final set of rolls.

After the dough has been sheeted, it enters the curling section. In the conventional moulder curling is done by special rolls. A more recently

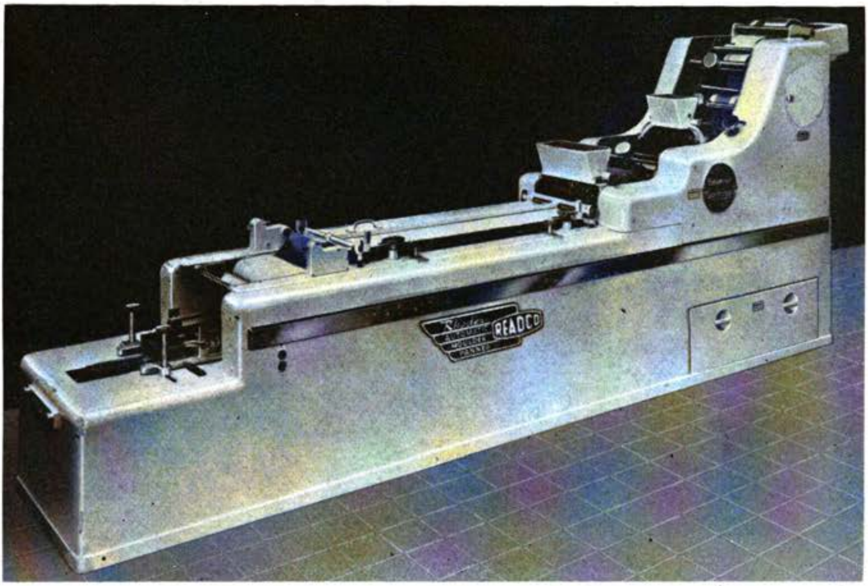


FIG. 146—Moulder-panner combines moulding with automatic positioning of dough piece in pan. Unit shown has reverse sheeting feature. (*Courtesy Read Standard Corp.*)

developed type of curling mechanism consists of two belts mounted in parallel fashion and traveling in opposite directions, with the curling belt or mat, resting above the conveyor belt, initiating the actual curling operation. In still more recent designs of moulders the curling mat consists of a short length of steel wire mesh or wide steel chain, attached to a rod at its front end, with the remaining section resting on the flat dough conveyor belt. As the dough sheet reaches the curling mat its front edge is engaged by the steel mesh and the dough given a so-called loose curl as it passes beneath the mat. In conventional operation the dough sheet has its lead-edge rolled into the center of the loaf. In contrast to this, a relatively new innovation is to have the sheeting section of the moulder at right angle to the conveyor which transports the dough sheet to the

curling mat and compression board, so that the dough is curled with its side edge forming the loaf center. This method of cross curling produces an elongated cell structure in the grain of the finished bread.

On leaving the curling section, the dough roll enters the compression mechanism in which it is subjected to sufficient pressure to seal all surfaces and to yield a dough loaf slightly longer than the bread pan. Two basic designs are in common use. One of these consists of a drum fitted with a semi-circular compression board, the drum section being faced

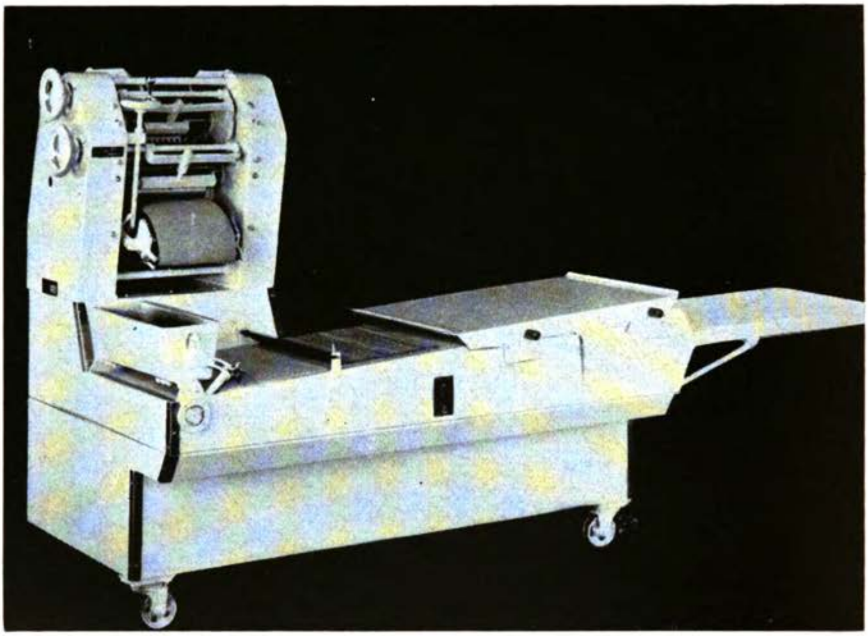


FIG. 147—Cross grain moulder. (*Courtesy Century Machine Co.*)

with canvas, while the pressure board offers a smooth surface. In the second design, the compression board is mounted horizontally over the flat conveyor belt carrying the curled dough pieces. Features normally incorporated in moulders include controls for regulating the speed of the moulder, the setting of the sheeting rolls, the amount of dusting flour applied, the length of the dough loaf, the degree of pressure applied by the compression board, and other variables.

Modern moulders are frequently provided with an automatic panning device, of which several types have been developed. Essentially, however, they all consist of a pan conveyor mounted integrally into the frame of the moulder; this conveyor carries the empty pans under the moulder head to a point just beyond the vertical compression board where an air

operated mechanism deposits a dough loaf into each pan. Automatic panning has been developed to such a high degree that there is no deformation of the dough piece in the process, and each dough piece is properly centered and deposited with its seam down.

Safety provisions: The American Standards Association (*230*) has proposed the following safety provisions in connection with the design and operation of moulders:

In moulders equipped with a mechanical feed, the hopper shall be so designed and connected to the intermediate proofer that an employee's hands cannot get into the hopper where they could come into contact with the in-running rolls. In hand-fed moulders, a belt feed device shall be provided or the hopper shall extend high enough to prevent the operator's hands from getting into the feed rolls. All edges shall extend high enough to prevent injury when struck by the operator's hands. A stopping device shall be placed within easy reach of the operator feeding the moulder and of the operator removing the dough pieces. There should be no shear point in close proximity of the clean-out holes. All revolving shafts at the rear of the machine shall have round corners or cylindrical surfaces, and all bolts shall be flush. There should be sufficient clearance between tie rods and revolving parts to prevent a shearing or pinching hazard. Where a removable crank is used to adjust the moulder for different sizes of loaf, brackets shall be provided on the side of the machine for holding the crank when it is not in use. The brackets should be connected to a limit switch to break the current when the crank is removed so that the machine cannot run unless the crank is returned to the resting position on the bracket.

FINAL PROOFERS

The panned dough next enters the final stages of fermentation in so-called final or steam proofers. Here conditions of comparatively high temperature and relative humidity are maintained to ensure a vigorous rate of fermentation. Conventional types of final proofers are built along lines similar to fermentation rooms described previously. Thus they are constructed of sectional panels consisting of a one-inch slab of insulating material faced on both sides with galvanized steel. The individual panels are set into a steel frame with the joints sealed in such manner as to prevent moisture penetration into the insulating material. Since the dough enters the proofer loaded on special racks which are difficult to manipulate, a multiplicity of doors is provided at both ends of the box, so that racks can proceed through the proofer in a straight line. With the use of caster-equipped racks the proofer has floor tracks installed to guide the racks and to protect the floor since the tracks provide

steel plates on which the casters run. Proofers are also available in designs that accommodate various types of suspended rack systems.

The air conditioning unit supplying the proofer is usually of the air washer type and is most conveniently located on top of the box. It is, of course, essential that the air-distributing ducts be so arranged that all parts of the box interior receive a uniform amount of fresh conditioned air, while at the same time the creation of strong currents is avoided. By placing either exhaust ducts or fresh air ducts at both ends of the proofer,

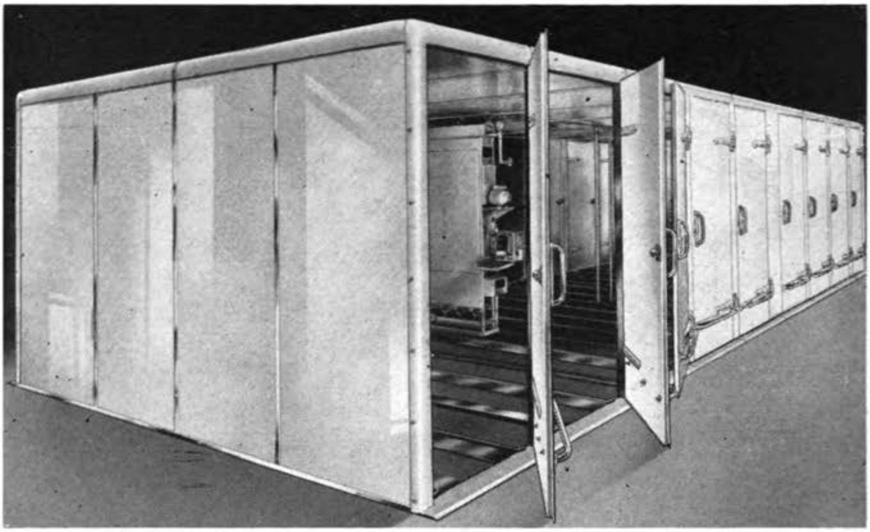


FIG. 148—Ductless air-conditioned proofing cabinet. (*Courtesy Anetsberger Bros.*)

temperature and humidity fluctuations within the box are held to a minimum when the doors are opened since the incoming outside air is either immediately exhausted, being drawn out by the exhaust ducts, or warmed to proofer temperature by the air being supplied by the fresh air ducts.

In addition to the conventional proof box described above, a second type of proofer, known as a traveling tray proofer, is used rather extensively in European plants and is also making its appearance in American plants. In this proofer the dough pans are loaded on wide trays which then travel within an enclosed overhead structure which in many respects resembles an overhead intermediate proofer. Proper atmospheric conditions within the proofer are maintained by a separate conditioning unit. The principal advantage of this type of unit is its relatively small floor space requirements, while its major drawback is its lack of flexibility as compared to the conventional proofer. Still another type

of steam proofer is the so-called tunnel proofer. It consists essentially of an endless traveling conveyor which carries the dough at a regulated speed through a tunnel whose interior is maintained at the proper temperature and humidity conditions. Here again, lack of flexibility constitutes a major problem. Furthermore, the unit occupies a great deal more floor area than do either of the other two types of proofer. Its application is justified only in the largest of bread plants operating on a completely automatic basis.

Proof boxes should be provided with doors whose locks are operable both from within and outside the box. The floor within the box should be of the nonslip type. All lighting fixtures should be vapor-proof.

CHAPTER XXVIII

OVENS

The baking oven is frequently referred to as the "heart" of the baking plant. It is the oven that converts the unpalatable fermented dough or aerated batter into bread or cake through the medium of heat. The manner in which heat is supplied, the control of the amount and intensity of heat required for proper baking, the cost of the construction, operation and maintenance of the baking unit, are all factors which have entered importantly into the design and development of modern ovens. Early ovens were little more than massive chambers constructed of brick or stone which were heated directly by building and maintaining a wood fire within the baking chamber until the oven had acquired sufficient heat to complete a baking run. In these ovens, the fire had to be pulled from the baking hearth prior to the start of the actual baking. Because of the need for storing a tremendous amount of heat in the hearth and walls of the baking chamber, these ovens were of massive construction, with walls several feet in thickness, and required days to heat and cool. Loading and unloading of these ovens were performed with the aid of peels and these ovens were consequently referred to as peel brick ovens. About a century and a half ago, the first improvement was introduced by equipping the peel ovens with a separate fire box or combustion chamber for heating. Heat was transferred from the fire box to the baking chamber by means of a series of flues both beneath and above the baking chamber through which the hot combustion gases were conducted on their way to the chimney stack. This development greatly expanded the baking period since the oven could be fired continuously to provide heat at baking temperatures for as long as was required. The oven, however, had certain inherent limitations, such as its excessive weight, the inability to control baking temperatures closely, the baking time differential introduced by the period required for loading and unloading, etc. Brick peel ovens of the type described are still in operations in a considerable number of older bakeries and perform satisfactorily when tended by skilled oven men. A variation of the standard peel oven is the so-called rotary peel oven in which the stationary hearth of the older oven was replaced by a circular, revolving hearth supported on a central, motor-driven axis. This was the first type of mechanical oven and represented a definite

improvement over the old peel oven insofar as loading and unloading was concerned and also with respect to an equalization of heat within the baking chamber. While some of the earlier rotary ovens still retained the traditional construction materials, later models, as a concession to the need for lighter oven weights, utilized metallic sheets for inner and outer wall construction, the walls housing the supporting steel beams as well as the insulating material. Other efforts to shorten the loading and unloading periods led to the development of various other modifica-

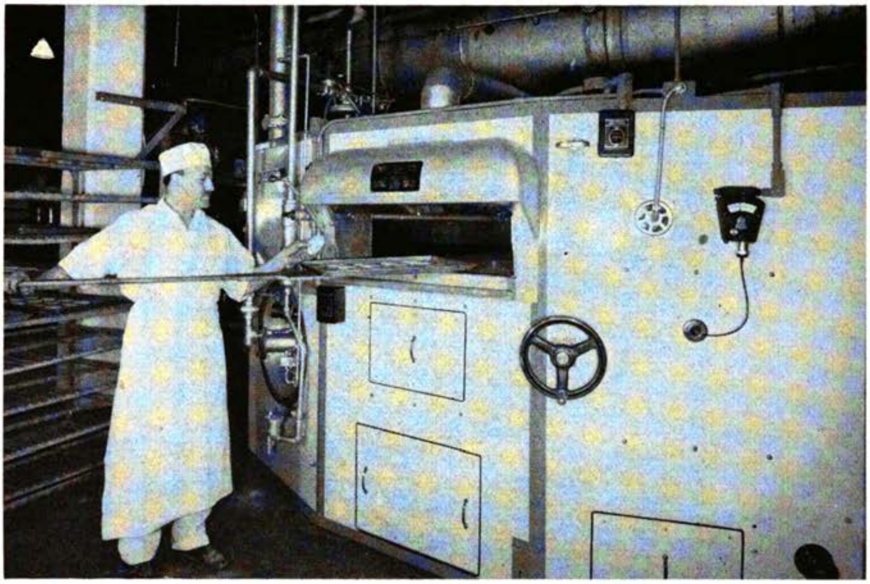


FIG. 149—Rotary oven having a diameter of 16 ft. (*Courtesy Baker Perkins Inc.*)

tions of the conventional peel oven, such as the draw plate ovens, twin table ovens, and rack ovens. In the draw plate oven, the hearth consisted of a large steel plate set on tracks which could be drawn from the oven for loading and unloading. In the twin table oven, whose use was restricted principally to Europe, the hearth was also movable, being drawn from the oven chamber on a special track for loading. The hearth, during the baking period, then turned end for end and thereby eliminated the occurrence of localized over-heating. This type of oven, however, failed to achieve general acceptance and soon passed from the scene. The rack ovens consisted of a brick baking chamber so designed that shelves on rollers and tracks could be run into and out of the oven.

The basic types of modern mechanical ovens may be listed as reel ovens, single lap ovens, double lap ovens, and traveling hearth ovens.

The selection of any specific type will depend largely upon the plant's production volume and availability of space. Thus for low production and limited space, the reel oven will be found most advantageous. Next in production capacity is the multi-cycle oven, in which the baking trays make several trips through the baking chamber. These ovens will bake from 1,000 to 2,000 lbs. of dough per hour, depending upon oven size. For production volumes of more than 2,000 lbs. per hour, either the single lap, double lap, or traveling hearth oven is indicated.

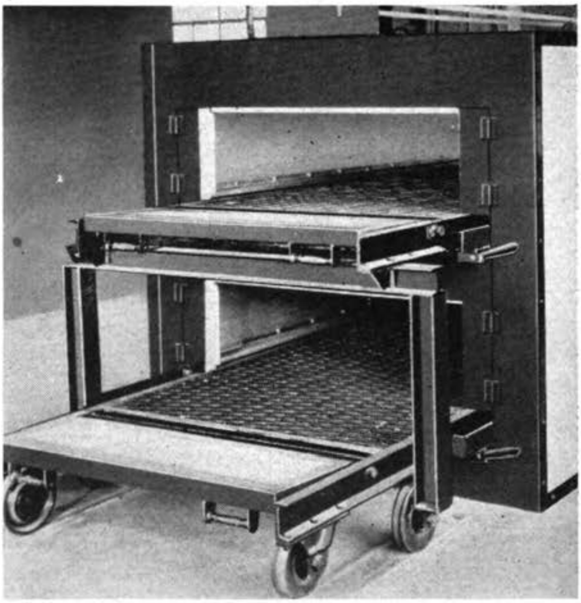


FIG. 150—Double deck drawplate oven, with hearth partly withdrawn. (*Courtesy Baker Perkins Inc.*)

Basically, a reel oven consists of a large baking chamber equipped with a vertically revolving double wheel which supports the baking trays suspended ferry-wheel fashion between the two side members of the double wheel. It has the largest relative baking chamber and hence its demands for heat are greater in relation to capacity than is the case with any other type of oven. It also makes more difficult proper heat distribution and close temperature control. Since the products pass several times through the upper steam zone in the course of baking, the bread or other baked goods acquire baked characteristics that differ from those obtained with traveling tray or traveling hearth ovens. Peel ovens are usually indirectly fired, i.e., the combustion gases do not enter the baking chamber directly. The fuel, which may be either gas, oil, or coal, is burned

in a fire box located under the baking chamber. The hot combustion gases are conducted across the underside of the baking chamber floor and upward at the back between the chamber and an insulated backwall out through the chimney. The floor of the baking chamber is usually made from some type of refractory, whereas the backwall of the chamber is normally of some metal, since the flue gases are of a lower temperature

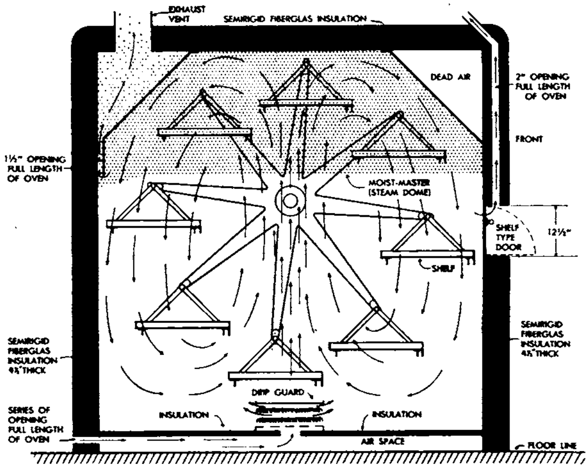
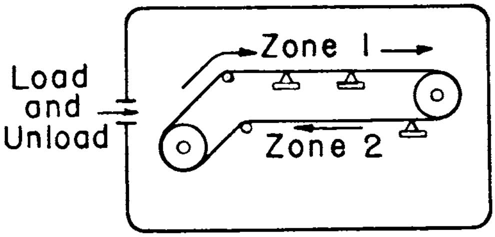


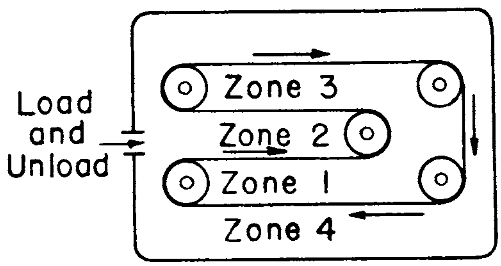
FIG. 151—Diagram showing the operation of a reel type oven. Dotted area at top shows entrapment of steam in upper third of the oven. (*Courtesy Despatch Oven Co.*)

at that point. The remaining insulated walls and ceiling may also be of metal.

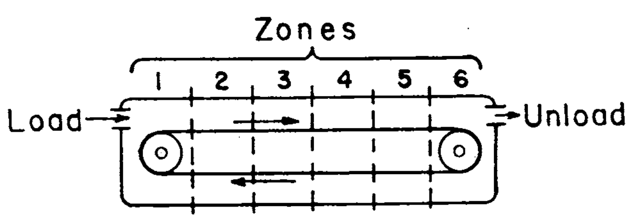
The traveling tray ovens, either of the multi-cycle or single and double lap design, are essentially modifications of the reel oven. They differ from their prototype by having a much lower horizontal baking chamber, in which the rotating wheel is replaced by endless chains which support the trays. In the multi-cycle type, in which the trays travel through the baking chamber several times during the course of the baking period, indirect heating is accomplished by means of flues or radiators through which the combustion gases are circulated. The single lap oven, in which the baking trays travel back and forth once during baking, and in the double lap oven, in which the trays travel back and forth twice during baking, are designed for larger volume operation. The single lap oven is generally considered to be basically the best tray oven because of its long horizontal runs, the long level steam zone, the simple construction, minimum duct work and generally simpler design. Larger units are usually equipped with multiple heating zones. They have capacities



(A) Single Lap
Single or Multicycle
TRAVELING TRAY OVEN
(up to 70' Long)



(B) Double Lap
TRAVELING TRAY OVEN
(up to 35' Long)



(C) TUNNEL OVEN
with Traveling Plate or Hearth
(up to 130' Long and 16 Zones)

FIG. 152—Schematic side views of common types of continuous and semi-continuous ovens. (*Courtesy Minneapolis-Honeywell Regulator Co.*)

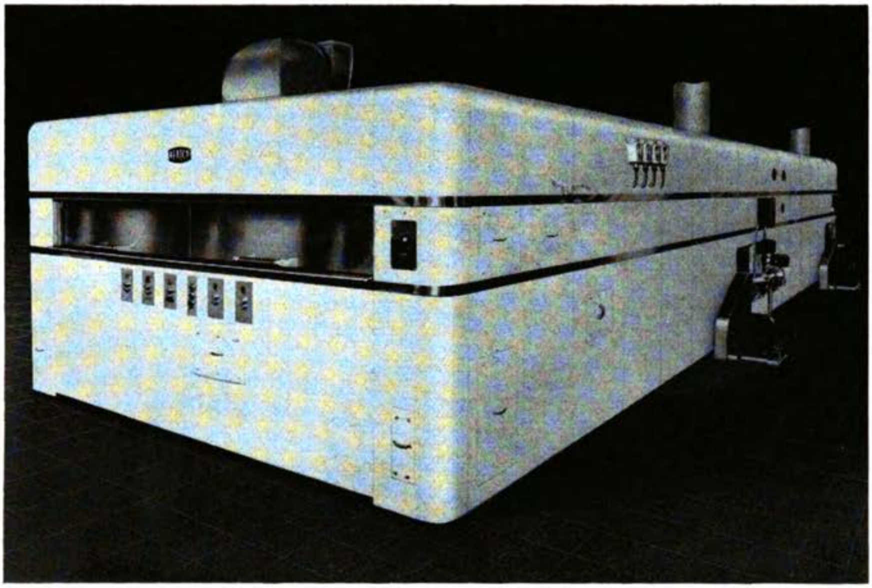


Fig. 153—Single lap traveling tray oven. (*Courtesy Read Standard Corp.*)

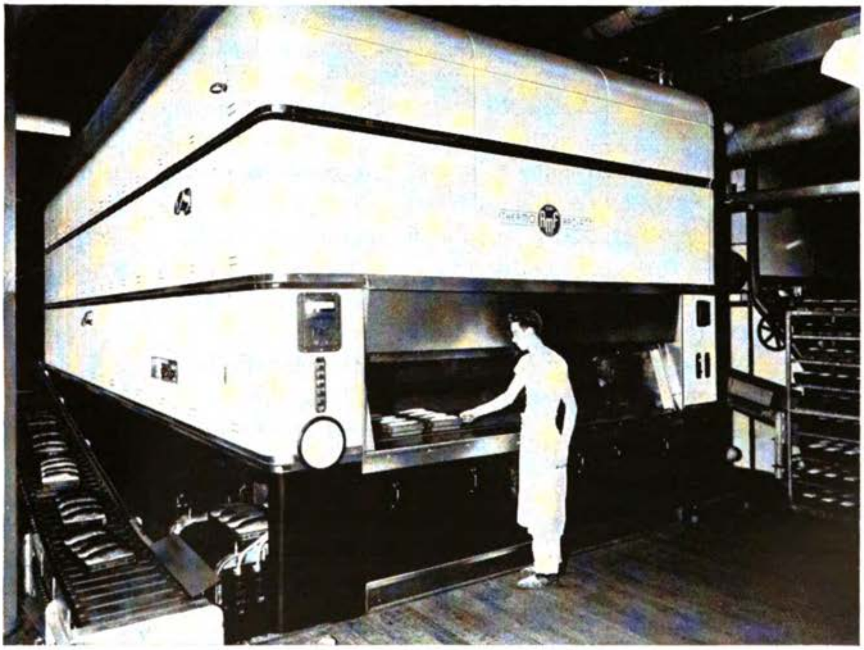


Fig. 154—Double lap traveling tray oven equipped with an automatic unloader. (*Courtesy American Machine & Foundry Co.*)

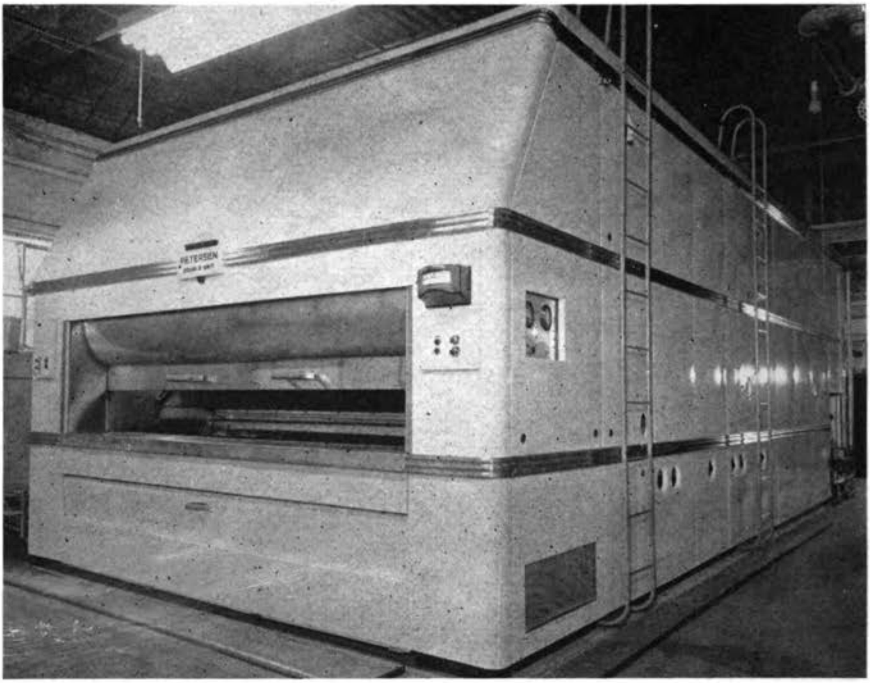


FIG. 155—Automatic double unit tray oven. (*Courtesy Petersen Oven Co.*)

ranging from 2,500 to 6,000 lbs. of bread per hour, depending upon the number of trays. The double lap oven, designed principally to utilize head room where floor space is inadequate to accommodate a single lap oven, is inherently more difficult to control because the baking zones are one above the other, with wide opening between them to permit the passage of the trays. It requires longer duct work and is mechanically more complicated than the single lap oven.

The traveling hearth oven or tunnel oven is designed primarily for large volume continuous operation. Here the hearth represents a motor-driven conveyor which passes through a series of heat zones at a rate that assures thorough baking of the goods. Loading is done at one end and unloading at the opposite end of the oven. The baking capacity of these types of oven ranges from 2,500 to 8,500 lbs. of bread per hour. While their initial cost is greater than the cost of tray ovens of comparable capacity, they have several distinct advantages. Thus, the long flat hearth has unlimited flexibility in respect to pan sizes, the oven is amenable to easy and accurate top and bottom heat control, there is no problem of tray stabilization, steam conditions are as close to ideal as can be desired, and heat control is simple, responsive and accurate.

FIG. 156—Tunnel type oven having a length of 100 feet and an hourly capacity of 4,600 lbs. of dough. (*Courtesy Baker Perkins Inc.*)

HEATING SYSTEMS

Before discussing the various systems of oven heating, it might prove desirable to review briefly the principles of heat transfer. Heat can be transmitted from one point to another in one or more of three ways, namely, conduction, convection and radiation. Conduction implies heat transfer through a solid object. Thus when one end of a metal rod is held into a flame, heat will rapidly travel by conduction through the rod so that the end held by the hand becomes hot. Heat is said to flow along the conductor. The rate of heat transmission in this case depends upon the nature of the conductor, some materials being good conductors, such as the metals in general, while others, such as asbestos, glass and mineral wool, wood, etc., are poor conductors and are for this reason used as insulators. Conduction formed the principal method of heat transfer in brick ovens where the heat generated in the combustion chamber passed by way of the flues into the fire brick and the baking chamber. Conduction is involved also in modern indirect-fired ovens by transmitting heat from steam or combustion gases through the tube walls into the baking chamber and through the pan material into the dough or batter.

Convection involves the transmission of heat from one point to an-

other through the medium of a substance capable of free circulation. Thus when water is heated over a flame, convection currents may be observed which cause the water to circulate and distribute the heat throughout the container. In an oven, the convection agents are air and steam within the baking chamber, and combustion gases which carry the heat from the fire box to the system of flues. So-called free or passive convection depends upon the natural air currents created by differences in temperature between adjacent air masses. Forced convection is obtained with the aid of a fan or blower. This type of convection results in a more rapid and efficient heat transfer and is hence frequently applied in oven heating. Convection is the principal mode of heat transfer in direct-fired ovens and also in the firebox-flue systems of all indirect-fired ovens. Some convection currents, either passive or forced, are also created in the baking chamber of all ovens.

Radiation forms the most complex mode of heat transmission. It differs from the two others in that it does not require a transfer agent. Thus the heat radiated by the sun strikes the earth after passage through millions of miles of absolute void. In its other general characteristics, the radiation of heat rays is similar to that of light rays since both types are fundamentally of the same nature, the heat rays representing the infra-red portion of the light spectrum. In common with light rays, heat rays travel in a straight line, may be reflected, pass through transparent substances, are stopped by opaque objects which they heat up as a consequence, and they diminish in strength by the square of the distance from the radiation source. Substances heated up sufficiently by radiation become in turn sources of radiation themselves. Also materials heated by convection or conduction give up their heat by means of radiation. Thus in baking ovens, any intensely hot object, whether it be the hearth, the baking chamber walls, the steam tubes, or the radiators of the thermoradiant system become sources of radiant heat which is transmitted to the baking loaves.

In ovens the three common heat sources employed are (1) indirect heating with steam sealed in tubes, (2) indirect heating by combustion gases conducted through flues, through tubes as in the diathermic or thermoradiant systems, or past large surfaces of the baking chamber such as the underside and backside of the chamber, (3) direct heating by the use of gas with ribbon-type burners. It is not uncommon to have different units of these types utilized in the same oven for heating individual zones.

In the steam-tube system, oven heating is performed by a series of high-strength, hermetically sealed tubes of approximately 1¼″ outside diameter which are partially filled with water or a heat-stable liquid

possessing a high boiling point. The tubes are so installed in the oven that a short portion of each tube protrudes into the combustion chamber, where direct heat is applied causing the water to vaporize into high pressure steam. The balance of the tube extends into the baking chamber. The tubes are slightly inclined toward the fire box so that steam condensate returns to the heated ends to be re-vaporized. Since saturated steam at atmospheric pressure has a temperature of 212° F., and since baking temperatures are normally within the range of 360° to 450° F., it is evident that considerable pressure must be developed in steam tubes to attain baking temperatures. Heat transfer in this system is principally by radiation and is hence governed by the physical law which states that the heat rays radiated from any one source vary inversely as the square of their distance. Therefore the steam tubes must attain much higher temperatures than the actual baking temperature. The magnitude of the pressure developed within the tubes is indicated by the fact that a temperature of 636° F. requires a steam pressure of 2000 lbs. per square inch. The use of steam tubes as a method of heating is slowly being discontinued in modern ovens as baking temperatures cannot be quickly raised or lowered.

The diathermic or thermoradiant system utilizes combustion gases from a burner which are mixed with cooled return gases and circulated within a sealed bank of tubes or radiators. Depending upon the size of the oven, several unit heaters are used. Each heater has a burner, recirculating fan, ducts, radiators and temperature controls. The combustion gases are rapidly circulated through the ducts and radiators from which the heat radiates into the baking chamber.

In the direct gas-fired system, gas and air are mixed in a common header serving 4 to 10 ribbon burners installed across the width of the oven. Depending upon the size of the oven, several headers may be installed, supplying heat to different zones. The direct-gas system is the simplest and most efficient method of oven heating. By proper design and distribution of ribbon burners, the gas can be consumed uniformly throughout the oven. The velocity of the combustion gases coming out of the burner ports, together with the natural convection currents created by the generated heat, supply sufficient turbulence to assure uniform temperatures throughout the oven as long as the size, number and location of burners are correct and the control equipment is properly engineered and installed.

Each type of oven has its advantages as well as disadvantages. Bakers have long considered the peel oven as the standard of comparison by which all subsequent oven performance is judged. Although the peel oven had its shortcomings, such as requiring a relatively large working

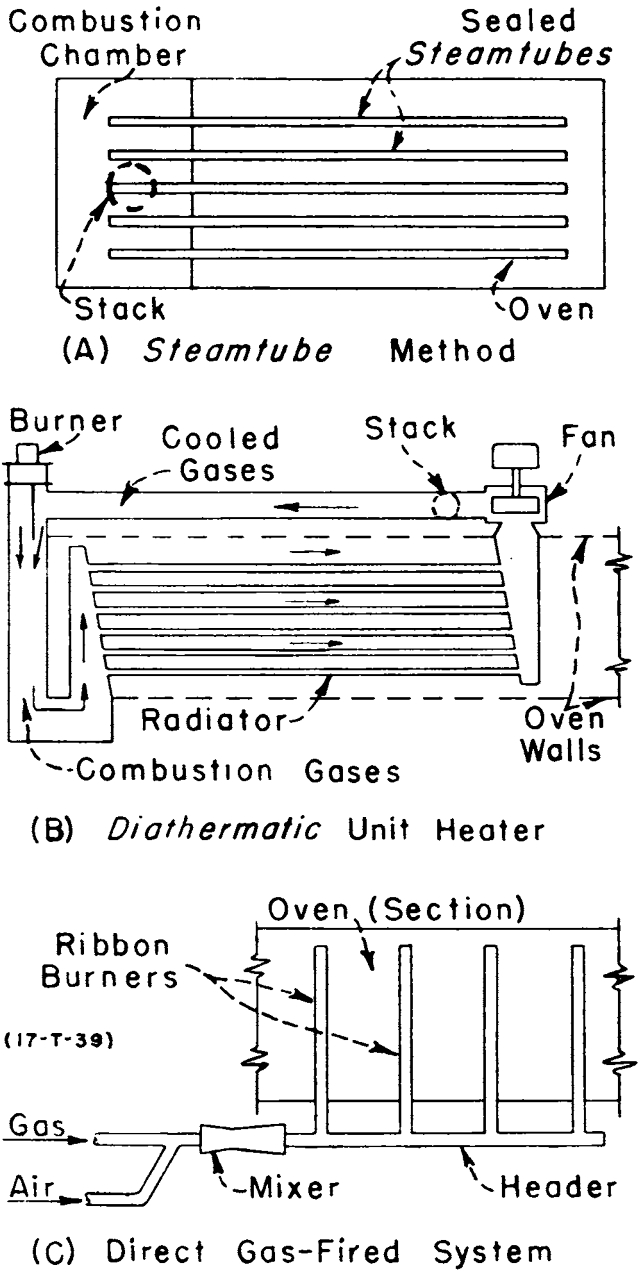


FIG. 157—Schematic diagrams showing methods of heating bake ovens. (*Courtesy Minneapolis-Honeywell Regulator Co.*)

area, lack of flexibility, the frequent occurrence of hot spots, etc., it did as a rule provide baking conditions which were long considered as ideal, namely solid bottom heat and a properly proportioned top heat obtained by radiation from the low ceiling which was seldom more than 1 foot above the hearth. With the introduction of mechanical ovens, this distance was considerably increased so that the beneficial effects of radiated top heat were more difficult to attain. In multi-cycle ovens, the height of the oven chamber is normally about 3 feet and the goods are exposed to the effects of radiated top heat for only half the baking period. In the reel oven, top radiation is almost completely absent. Here, on the other hand, the occurrence of heat pockets in the upper portion of the baking chamber frequently represents a problem unless this condition is corrected by proper engineering design. Another difficulty encountered with modern ovens in which the height of the baking chamber is increased to allow for the vertical movement of the trays is the formation of heat stratification, or the creation of vertical heat zones, each with its different temperature and moisture condition, and each with its different effect upon the baking product. The use of baffles and of forced convection has been partially successful in overcoming this problem. Large baking chambers also make it more difficult to establish the correct degree of steam saturation throughout the baking area and also create the tendency toward eddy currents in the convected heat which may result in non-uniform baking. The great advantages of modern mechanical ovens, on the other hand, resides in their heat flexibility, i.e., the quick adjustment of the heating mechanism to the temperature requirements of the particular kind of product being baked. This has been accomplished by reducing to a minimum the use of refractory materials which tend to store heat, and by a greater emphasis of convection as the mode of heat transmission. In this connection, there has been a steady trend toward the use of so-called "grid" or "grill" trays made of metal to replace the solid trays made of soapstone. While the solid trays provide a more even heat, they require longer to heat up and, because they store a great deal of heat, also to cool down and hence reduce the heat flexibility of the oven. Also, solid trays transmit heat to the pan principally by conduction, thereby supplying more heat to the bottom of the pan than to its sides. While this is desirable in pie and cake baking, it cannot be equally recommended for pan bread baking. In the open or grid type tray, on the other hand, convected heat passes through the grill work and therefore heats the pans more evenly on all sides. Hence more uniform heat reaches a great pan area and the baking process is accelerated. The evolution of modern oven designs has been described by Ludlow (*232*), Kylberg (*233*), Berhans (*234*) and others.

OVEN LOADING AND UNLOADING DEVICES

In smaller plants and with ovens of limited capacity, the loading and unloading of tray ovens is performed manually by the oven man who must dump the baked bread on a dumping table or conveyor, place the hot pans on a pan truck and load the oven with panned dough, carrying out these operations with a minimum loss of time. The larger the oven size, the greater the difficulty of loading and unloading the oven efficiently and the more desirable the installation of an automatic loader and unloader becomes. As a general rule, tray ovens with 32 shelves or more should be equipped with automatic loading and unloading devices. The basic principles of these devices are rather simple. In the case of automatic loaders, the loading device consists of a pusher bar whose movement is synchronized with the travel of the trays. The oven man places the pans upon the oven's loading platform and as the tray moves into position, the pusher bar moves forward and slides the pans onto the tray, after which it returns to its rest position. Variations in design concern principally the actuating mechanism of the pusher bar and the manner of its return. In some instances the pusher bar moves in and out at a uniform level, in others, it returns to its starting position by traveling at a higher level, and in a third method the pusher bar disappears on its return trip under the loading platform and comes up into starting position around the rounded front end of the loading plate. The advantage of the last two arrangements is that loading can be carried on more continuously since there is not need for awaiting the return of the pusher bar to its rest position. The underhand return is particularly efficient since there is no danger of the bar descending upon carelessly placed pans. Automatic unloaders usually provide for a tilting mechanism which tilts the trays carrying the baked bread just before they reach the loading position, causing the pans of baked bread to slide onto a cross conveyor at a lower level which then carries the pans to an opening at the side of the oven. Here the pans are generally transferred mechanically onto a conveyor leading to the dumping station.

BAKING FUELS

The principal fuels used in baking are gas, oil, and coal, with electricity finding only limited application for small batch baking. The selection of a particular fuel will be governed by a number of considerations, such as cost, efficiency, availability, and conveninece. In Table 137, adapted from data by Kylberg (*235*), the various types of fuel are compared with respect to their heat value per unit and the respective amounts required to bake 1000 lbs. of dough.

The values of the respective quantities required to bake 1000 lbs. of dough imply continuous baking and show that this amount of dough requires 120 KWHs of electricity, or 1000 cu. ft. of gas, or 5.5 gallons of oil, or 100 lbs. of coal for baking. The cost of fuel per 1000 lbs. of dough may be calculated from prevailing base costs per unit of fuel. Under normal fuel supply conditions, it will be found that natural gas yields the lowest cost figure, while electricity is the most expensive heating agent, the other types being intermediary, but generally closer to the cost of gas.

TABLE 137. COMPARISON OF COMMON FUELS

	Heat value in BTU's per Unit	Quantity required to bake 1,000 lbs. of dough
Electricity	3,412/KW	120 KW
Manuf. gas	550/cu. ft.	1,000 cu. ft.
Natural gas	1,000/cu. ft.	500 cu. ft.
Fuel oil, light	140,000/gallon	5.5 gals.
Fuel oil, heavy	160,000/gallon	7.0 gals.
Coal, anthracite coal and coke	13,500/lb.	100 lbs.

Some of the general considerations with regard to the use of different fuels are the following: Coal requires storage space which may frequently be at a premium. Extra labor is needed for handling the coal and ashes and for tending the firing box. Coal fires have limited flexibility, whether hand or stoker fired. Variations in heat content between different shipments of coal are greater than with any other type of fuel. Efficiency of heat utilization is at best only about 30 percent of theoretical value. Fuel oil occupies less space than coal and is easier to handle. Burned in a properly designed oil burning equipment, it provides cleaner operation, about 10 percent more efficient heat utilization, and greater flexibility than coal. On its debit side are the high service and replacement costs on oil burning equipment. Gas requires no storage space or handling. It gives clean heating, possesses the greatest flexibility of all fuels, and has an operating efficiency of 40-50 percent, as reported by Kylberg (*235*).

INSTRUMENTATION

Modern ovens are equipped with various types of control instruments of which the most important ones are concerned with temperature regulation. The devices used in the control of oven temperatures range in complexity from the simple pressure-type thermometer to electronic potentiometers. Every baker is familiar with the common glass stem

thermometer as a temperature indicating instrument. The principle used in this thermometer, namely the expansion with increasing heat of the mercury or other liquid fill, is also applied to various more complex temperature controllers. In the so-called non-indicating self-acting controller, the pressure created by the expansion of the filling medium may be directly exerted on a valve to yield temperature control within fairly narrow limits, or the pressure may expand a bellows to tilt a mercury switch, thereby making or breaking an electrical circuit used to change

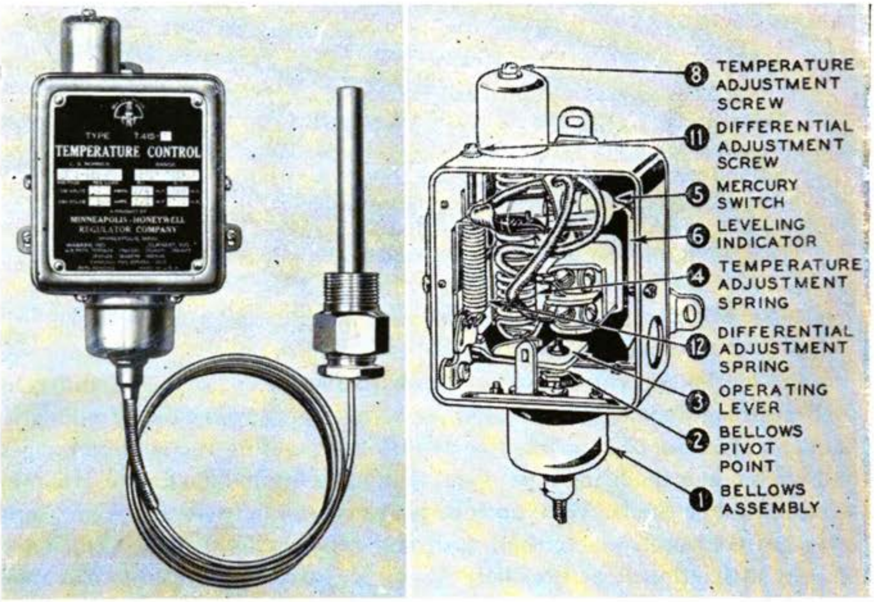


FIG. 158—Non-indicating temperature controller. (*Courtesy Minneapolis-Honeywell Regulator Co.*)

the position of an electrically driven valve. Further refinement in this type of controller results in so-called indicating controllers in which the expansion of the filling medium is applied to a hollow coiled ribbon which tends to straighten out under the influence of pressure, thereby giving a relatively large amount of motion for a slight change in temperature. This results in greater accuracy for the indicating controller, since the spiral element responds with greater sensitivity to temperature changes than does the bellows of the non-indicating instrument. This movement of the spiral elements may be translated into control action by a variety of devices, all having the property of being easily and accurately set to give control at any point within the range of the instrument. A single indicating controller may govern the operation of more than one valve

to provide control action at more than one temperature. Finally, it is possible to add a pen and chart to the instrument with a clock-type chart drive to yield a continuous record of the temperature progress. The recording thermometer thus provides a permanent record of temperature levels at given times. Since the thermal element can be mounted at a distance from the instrument and since several thermal systems can be installed in the same instrument case to record up to three temperatures on the same chart, this instrument may be used for recording temperatures at various different points. The pressure-type thermometer in its various modifications indicated above has an accuracy of ± 1 percent of the scale span.

The fact that the electrical characteristics of metals undergo certain measurable alterations with changes in temperature has been utilized in the development of the pyrometer for the measurement and control of processes involving heat. Temperature has two significant electrical effects: one on the resistance or conductivity of a wire, and the other on the voltage that is generated at a point of junction of two dissimilar metals. The first effect is utilized in the resistance thermometer, and the second in the thermocouple pyrometer. In the resistance thermometer the measuring element is simply a measured length of wire whose resistance varies in exactly known increments with changes in temperature. In the thermocouple pyrometer the sensing element is a thermocouple which consists of a welded joint of two different wires. When two metals of different composition are in contact, a voltage which varies with the temperature is produced at the junction and can be read on an instrument calibrated in terms of temperature degrees. The instrument to which the thermocouple is connected may be either a millivoltmeter pyrometer or an electronic potentiometer pyrometer. Although the millivoltmeter type pyrometer is calibrated in degrees Fahrenheit, it is simply an extremely sensitive galvanometer, powered by the thermocouple voltage. When used as a control instrument, a motor is provided to supply power to automatically "feel" whether the pointer is above or below the desired temperature, and to give control action without imposing any load on the pointer itself. These instruments are sensitive to 1 percent of scale span and are capable only of periodic control action which is adequate for regulating some ovens. Where closer control is required the electronic potentiometer, which gives instant and continuous response to temperature changes with an accuracy of ± 0.25 percent of scale span, and a sensitivity of $\frac{1}{32}$ percent, is recommended. A motor drive is used in this potentiometer to balance the thermocouple voltage against that of a reference cell, making it possible to use much more elaborate control forms with no fear that they may affect the accuracy of measurement. This

instrument is used mostly in the high speed ovens of biscuit and cracker bakeries. A more detailed discussion of temperature indicating and control devices has recently been made available by Meyer (*236*).

Both the pressure type thermometers and the electrical pyrometers are used in the control of oven temperatures. The thermometers are frequently applied in controlling the temperature of small ovens, or of separate zones of large ovens. Representative readings are made possible with this instrument by using an "averaging bulb" which is merely an elongated version of the familiar element. By lengthening the sensing element, it is made responsive to temperatures over a wider area and provides an instrument reading that is the average for that area. The inherent advantages of the thermometer type instrument have been listed by Meyer (*236*) as follows: (1) low cost where only one instrument is used; (2) separate continuous temperature readings for each control zone in multi-zone ovens; (3) long operation with a minimum of service or maintenance; and (4) continuous daily charts where recording thermometers are used. However, this instrument also has certain limitations. Thus, if four controlling thermometers are being used on separate zones of an oven, and the thermal system at one is damaged, the instrument needing repair can be removed and its section of the oven placed on manual control while the other three instruments continue to function. But unless a spare capillary system is kept on hand at the bakery, several weeks may elapse while the instrument is repaired, tested and calibrated at the factory. Also, a separate thermal system is required for the control and measurement of temperatures in each separate zone with this type of instrument.

Electrical measuring and controlling systems have been widely adopted to overcome some of these objections and to provide additional advantages. The most common and least expensive electrical instrument is the indicating millivoltmeter pyrometer. Since it is possible to connect a single instrument to any number of thermocouples through a simple switching arrangement, or to more than one thermocouple when an average reading is desired, a single electrical instrument is often used to measure several temperatures within the oven. It is desirable, however, where several burners are used, to install individual instruments for each zone. Also, it will prove advantageous to use a separate recording instrument in conjunction with indicating controllers to produce a chart showing the oven temperature in each of the zones during the baking cycle. The millivoltmeter pyrometer generally utilizes an electrically driven motor to "feel" the position of the indicating pointer several times a minute. If the pointer falls below the control setting, an electrical contact is closed, actuating the burner. Similarly, if the temperature rises above

the set point, the burner is shut off. This arrangement permits the maintenance of the oven temperature within fairly close limits. Even closer control may be achieved by the use of a manual by-pass which allows a minimum amount of fuel to flow to the burner at all times. Since the amount of fuel being added or withheld by control action is thereby reduced, the fluctuation in temperature is correspondingly decreased.

For extremely close temperature control in high-speed tunnel ovens the electronic potentiometer offers the greatest possibilities. It may also use the thermocouple as the sensing element, but the increased sensitivity of the instrument itself gives much more precise temperature control.

The control unit used with the pressure type thermometer or electronic potentiometer may be either electric contact control or pneumatic proportional control (narrow band throttler), the choice depending largely upon the burner used in the heating system. The control can provide either high-low, on-off, or proportional regulation. In the high-low system, the burners operate at high capacity when the controller calls for heat, and at a predetermined low setting when the heat requirements of the controller have been satisfied. In the on-off system, the minimum is set to the off position on the gas or oil valve. When heat is called for by the controller, the burner is re-lit and operates at high capacity. The on-off system may also be used to automatically control the setting of dampers operated by a two-position motor with a limit switch. In general, the high-low control will be found preferable since it minimizes cycling of the temperature about the controller set point. The type of control unit gaining rapid acceptance in recent years is the narrow-band throttler which gives the proportional control necessary to correct the temperature fluctuations that may be encountered in ovens. The throttler unit, by regulating the air pressure on a diaphram-operated proportional control valve, supplies control action of sufficient magnitude to promptly restore the temperature to the desired level and prevent all but minor fluctuations.

The location of the temperature sensitive element in each controlled zone should be such that it will respond quickly to any changes in temperature. The exact positioning will, of course, depend upon the design of the oven, the extent of heat lag from the heat source to the baking chamber, and the speed of the detecting element. These factors have recently been discussed in greater detail by Cuckler (*237*).

In addition to temperature indicating and control devices, modern ovens are equipped with various other controls. Thus the speed of travel or baking time of traveling ovens is usually measured by means of a tachometer which utilizes a generator geared to the conveyor so that its

speed of rotation varies directly with baking time. Since the voltage output of this generator will then vary with the speed of the oven, baking time can be measured either by an indicating or a recording instrument. Some form of combustion safeguard is standard equipment on all modern ovens as a means of protecting personnel and equipment against the results of flame failure. The most reliable instruments for this purpose are flame electrodes or photoelectric cells and may be operated in conjunction with other devices which shut off the flame in case of an unsafe drop in fuel pressure, excessive pressure, excessive temperature in the combustion chamber or stack, or any unusual condition which would render operation unsafe. The flame electrode is based on the fact that a flame, being highly ionized, is an electrical conductor and can be made a part of an electrical circuit. When this circuit is complete, it closes a relay to hold the fuel supply valve in the open position. This valve is of the normally "closed" type so that it will shut off the fuel supply in case of fuel or power failure. In the photoelectric cell system, a light-sensitive detecting unit is sighted on the flame and keeps a relay closed while the burner is lighted. When the flame goes out, the photoelectric cell responds by dropping out the relay, operating safety devices in the same manner as the flame electrode. Either of these systems can be equipped with relighting devices which will re-light the flame when the shut-off valve is also being used for the purpose of temperature control.

The safety code proposed for ovens by the American Standards Association (*230*) covers a wide variety of conditions and situations, ranging from the selection of the best oven site and the safest procedure of installing the unit to safety features and precautionary measures pertaining to the mechanical and operational parts of the various types of oven. Since the code is too lengthy to permit its detailed review within the limited scope of this discussion, the interested reader is referred to the original safety code.

CHAPTER XXIX

BREAD COOLING, SLICING AND WRAPPING EQUIPMENT

Depanning. Bread emerging from the oven is removed from the pans and permitted to cool prior to being sliced and wrapped. Depanning may be done manually or mechanically by a special automatic depanning unit of which several similar designs are available. The fundamental se-

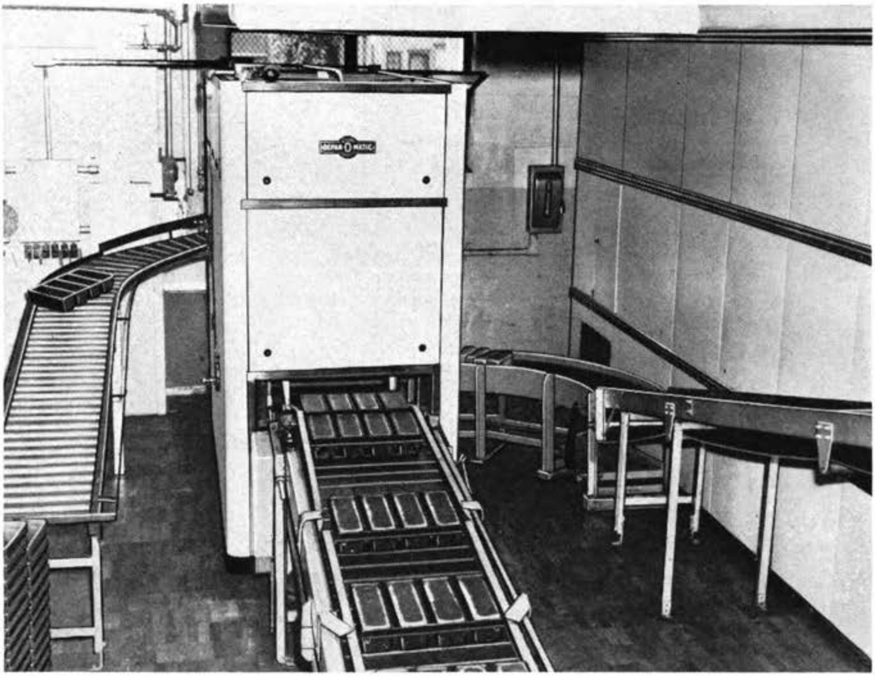


FIG. 159—Bread depanner installation showing panned bread being fed to unit in front, with bread and empty pans emerging on either side. (*Courtesy Petersen Oven Co.*)

quence of operation of all automatic depanners is the same. The strapped pans with the freshly baked bread reach the depanner unit by means of a conveyor and are picked up by shelves which move upward toward a dumping station. As each shelf reaches the end of its upward

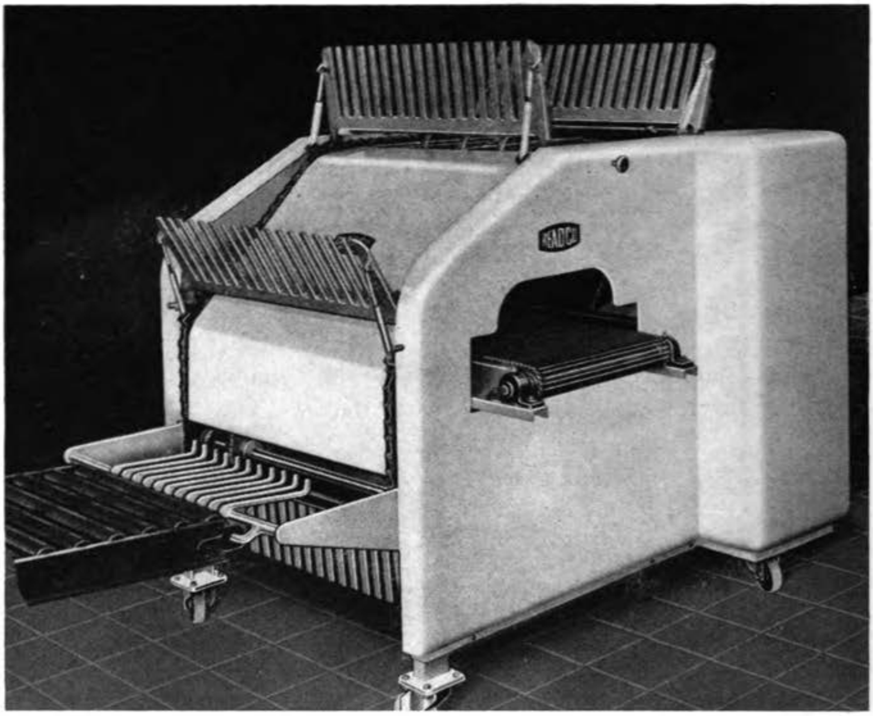


FIG. 160—Automatic bread depanner. (*Courtesy Read Standard Corp.*)

travel it turns in a horizontal direction and causes the pan to fall over against a bumping bar. The bread is jarred loose and slides by means of a turn-over chute onto a conveyor below which carries it to the bread cooler. The pans, in turn, are turned to their upright position and deposited onto the pan conveyor which carries them through the pan cooling section and back to the pan greaser or moulder. The time of travel between the depanner and the moulder-panner is so adjusted that the pans cool off sufficiently to be ready for immediate re-use on arrival at the proper station.

Bread Coolers. While bread cooling is still largely carried out by exposing the bread, stacked on bread racks, to the atmosphere, the use of special bread coolers is finding increasing application in bread plants striving toward automatic production. Cooling bread on racks is a time-consuming, laborious and uncertain process, since it is markedly influenced by prevailing atmospheric conditions which are subject to drastic seasonal variations. Under high humidity conditions, bread must frequently remain on the racks for an unduly long time if it is not to reach the slicer too warm. Furthermore, rack cooling requires a considerable

amount of floor space which may not always be available. An improved method of bread cooling consists of an enclosed traveling conveyor arranged in multiple tiers which may be suspended from the ceiling above the oven. The bread from the oven is loaded either manually or mechanically on trays and conveyed to the top run of the unit and is then slowly conveyed back and forth until it reaches the discharge end ready

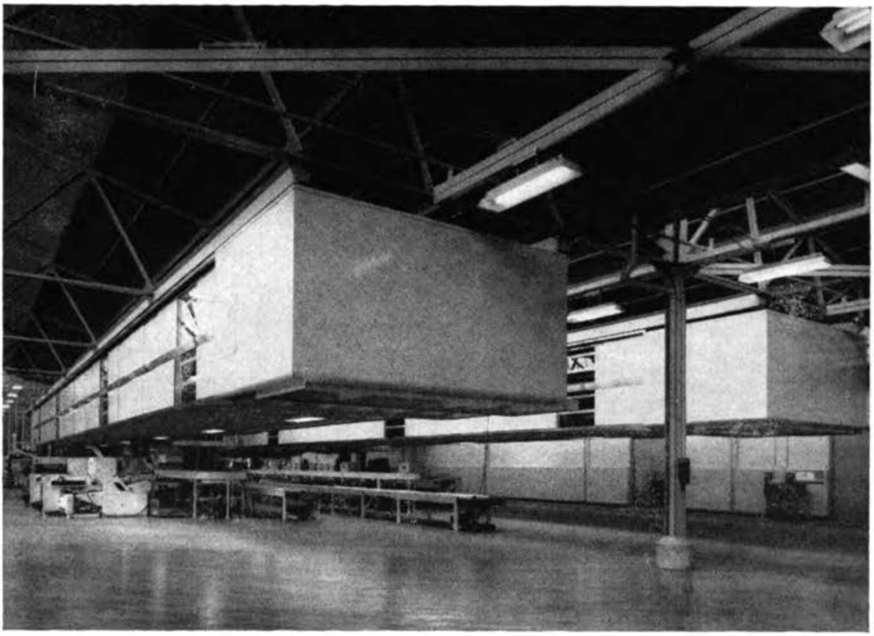


FIG. 161—Automatic overhead bread cooler. (*Courtesy Helms Bakeries.*)

for slicing. This type of cooler is usually equipped with an air exhaust system which draws in fresh air at the discharge end of the unit, passes it slowly upward past the cooling loaves, and exhausts the warm air at the top. A further improvement is represented by the tunnel-type conditioned cooler which is essentially an enclosure provided with an air conditioning unit. The hot bread, either on trays or on racks, enters the cooler and is progressively cooled as it moves toward the exit doors, with the conditioned air flowing past it in cross-current or countercurrent fashion. The latest advance in bread cooling devices is represented by the vacuum bread conditioner which consists of a conditioning tunnel in which the hot bread is tempered by washed air of controlled temperature and humidity. Following this pre-cooling stage, the bread enters a vacuum chamber for a two-minute period where temperature equalization throughout the loaf is obtained with the aid of vacuum. The princi-

FIG. 162—Conveyor-cooler for hard rolls. (*Courtesy Burny Bros. Bakeries.*)

pal advantage of the vacuum cooling process is that it will yield loaves of unusually uniform temperature and crust firmness, regardless of prevailing outside atmospheric conditions.

American Standards Association safety measures (*230*) for bread coolers of the conveyor type provide that all pinch points be eliminated or guarded and that stop bumpers be installed on all delivery ends of conveyors wherever manual removal of the product is practiced, to prevent the bread being carried to the extreme end of the conveyors where pulleys, sprockets or chains are located. In rack type bread coolers, guard rails are called for so as to center the rack as it enters and leaves the cooler. All door locks shall be operable from both within and outside the unit. Where the cooler has no side guides or overhead rail the floor should be of the nonslip type.

Bread Slicers. Bread slicers come in two basic designs, differing essentially in the mode of slicing. The so-called reciprocating slicer makes use of slicing blades mounted in two frames which move up and down at a high speed in opposite direction, cutting the loaf as it is gently pushed through the moving blades. While this type of slicer is still used extensively, especially for rye breads and hard-crusted specialty breads,

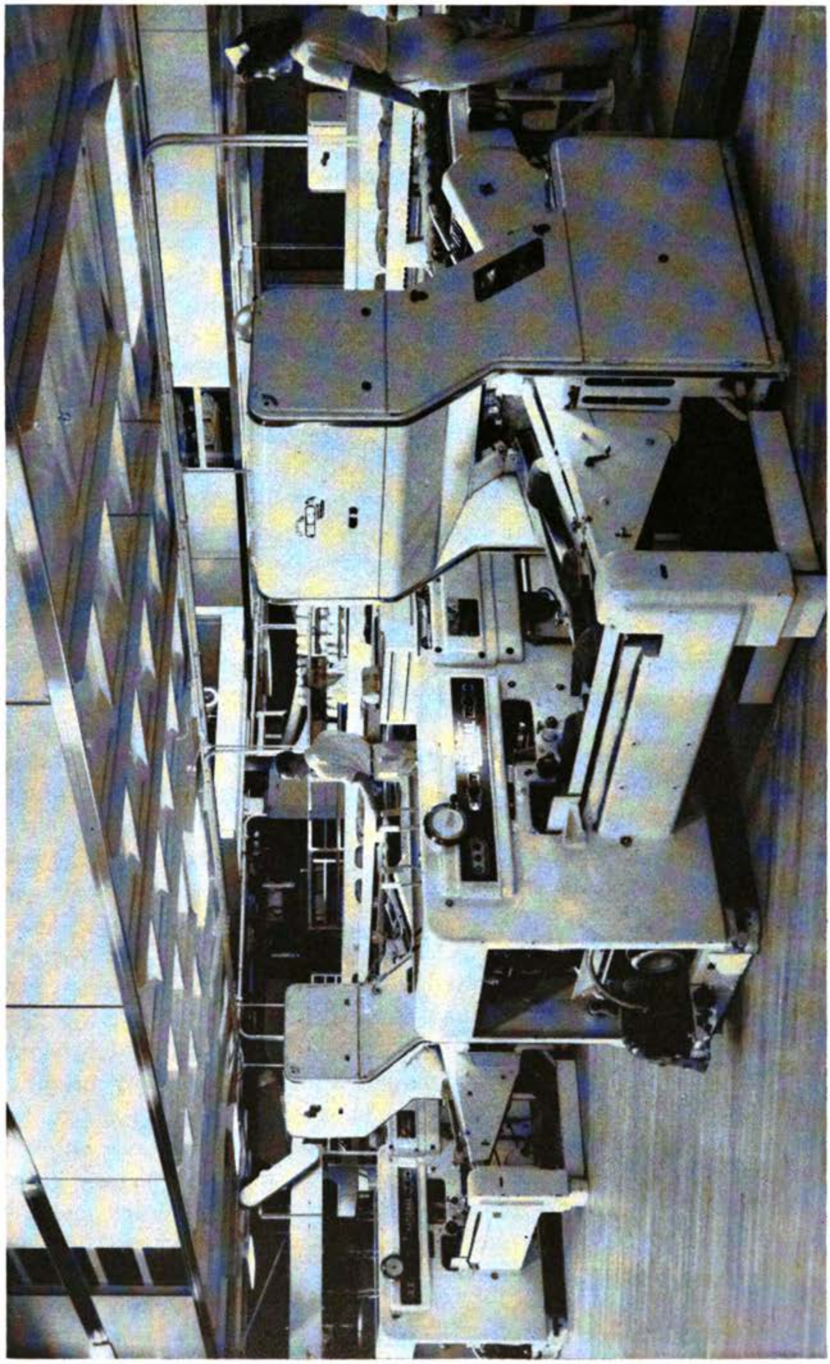


FIG. 163—Interconnected bread slicing and wrapping machines. (*Courtesy Helms Bakeries.*)

the trend is toward the so-called band slicer. Here the slicing blades are endless band knives which are rotated at high speed by a set of revolving drums located respectively at the top and bottom of the machine. Guides direct the cutting edge of the blades at right angle to the longitudinal center line of the loaf which is moved through them. Band slicers cut up to 60 loaves per minute with a minimum of crumbs and loaf deformation. Modern designs emphasize slicing speed, sanitation, safety and flexibility in slicers. Currently available units are heavy duty, streamlined machines in which all moving parts are guarded with safety interlocks, and the interior corners and crevices are readily accessible for cleaning. Because different markets demand different slice thicknesses, modern machines are usually equipped with adjustable blade spacing or interchangeable blade frames.

American Standards Association safety provisions for slicers (*230*) include (1) the complete enclosure of all sprockets, chains and V-belt drives; (2) a mechanical device on new machines for pushing the last loaf through the slicer knives, and a block on a hinged arm in old machines for the same purpose; (3) an interlocking arrangement on the cover over the knife head of reciprocating slicers so that the machine cannot operate unless the cover is in place; (4) on band slicers, each motor shall be equipped with a magnet brake which operates whenever the motor is not energized; each door, panel, or other point of access to the cutting blades shall be equipped with an interlock which will stop the machine whenever a door, panel or access point is opened; (5) when it becomes necessary to sharpen the blades on the machine, a barrier shall be provided which leaves an opening sufficient only for the sharpening stone to reach the blades; (6) where pusher fingers attached to the feed chain enter the bed plate of the cross feed, the end guard shall be extended to cover the pinch point.

Bread Wrapping Machines. Although the conventional bread wrapping machine is a rather complicated unit, its basic operational parts can be reduced to a few distinct mechanisms. The first of these is the feed mechanism, consisting of chains and flights equipped with guides, which receives the loaf from the slicer and carries it into the wrapping machine. For efficient passage of the loaf from one machine to the other the guides are set so as to provide approximately a quarter inch clearance on each end of the loaf. Frequently a loaf emerging from the slicer has a slightly crushed appearance and by providing a slight leeway on each end the loaf is allowed to regain its normal form. The guides narrow to loaf length at the end of the feed mechanism.

From the infeed mechanism the loaf next enters the elevator or lifter table. In some types of wrappers the infeed chains transfer the loaf onto

the elevator, while in others special pusher plates perform the transfer function. Some wrapping machines have their elevator equipped with a back tension plate. This plate should move very freely so as not to exert a pressure on the soft loaf and deform it. The plate should be checked frequently both as to its freedom of movement and its lubrication.

The loaf receives the paper or cellophane while on the elevating mechanism. This is accomplished by various means, depending upon the particular unit. In some machines the paper is pulled, while in others it is fed in by pusher bars. The condition of the paper influences considerably the efficiency of the paper feed. Thus wax paper tends to assume a

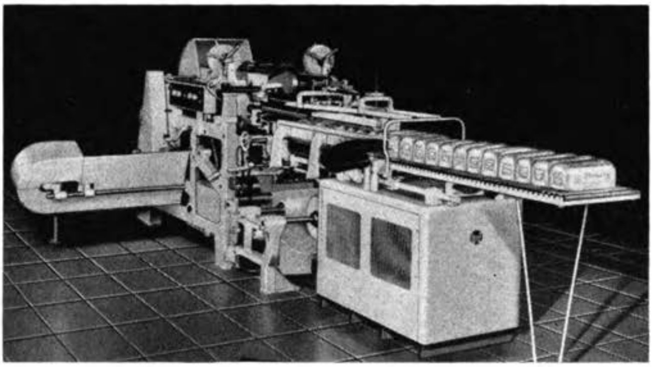


FIG. 164—High speed wrapping machine capable of wrapping 65 loaves per minute. (*Courtesy American Machine & Foundry Co.*)

tacky character when it is stored at temperatures in excess of 100° F., whereas cold storage causes it to become brittle. Cellulose also becomes brittle and weak on cold storage or when it has been kept for an excessively long period. Proper wrapping presupposes correct alignment of all bars, fingers and belts that carry the paper. The paper cutter, whether of the shear type or the saw tooth type, must be kept sharp to provide a clean cut without pulling or tearing. The paper feed adjustment should be such as to supply a minimum overlap of 2 inches on the bottom of the loaf. A larger overlap will generally be found desirable since it will supply a firmer backbone to the loaf.

The next operation imparts the first fold by means of so-called tuckers, which are two plates positioned either vertically or horizontally, depending upon the type of wrapping machine. The kind of first fold obtained is all-important for the subsequent three folds. If the first fold is smooth and straight the remaining folds will be the same. If the tuckers are of improper size, or if the wrapping paper is either too stiff or too soft for the purpose at hand, the fold may then be wrinkled or improperly

creased, and the subsequent folds will also be defective. Hence the entire folding operation should be closely adjusted, with the right size of tuckers being employed.

The package, with the ends folded, next passes through the heating section or station whose purpose it is to melt the wax at the end folds and bottom overlap to obtain a seal. The heating element should be controlled by means of thermostats to ensure the correct temperature whose proper level is governed by the speed of the machine, the type of wrapping material, and the temperature of the loaf, paper and room. The sealed package then passes past cooling plates, through which either cold water or a refrigerant is circulated, which quickly reduce the wax to its solid state and thereby secure the seal.

In regular production the wrapping unit is usually integrated with the slicer, the two machines being connected by means of flight conveyors which effect the automatic transfer of the sliced loaf to the wrapper. Modern wrapping machines are normally provided with many refinements and features, such as hot and cold plates for rapid sealing of the paper or cellophane, outsert and insert attachments, end-seal applicators, and label printers.

In recent years the practice of so-called duplex or twin-pack wrapping of bread has gained some prevalence as an aid to bread merchandising. In this method the loaf of bread is sliced and separated into two equal halves, each half being then wrapped individually. The two half-loaves are then recombined into one package by wrapping them together. As an added refinement the final wrapper is equipped with a tear strip to facilitate opening the package. The advantage of this type of packaging is, of course, that a half loaf may be served by the housewife at a time, with the other half remaining tightly wrapped and protected against rapid drying out. Furthermore, by combining half loaves of two different types of bread, such as white and whole wheat, a dual loaf may be merchandised.

The American Standard Safety Code (*230*) contains the following provisions pertaining to slicer-wrapper connections: (1) Where the flight chain on the slicer turns under the bed plate on the cross feed to the wrapper, a spring-hinged section of bed plate shall be provided to eliminate any shear point between the flight chain and the bed plate. (2) The slicer and wrapper shall be so installed and connected that the chains, sprockets, belts, and moving parts are properly guarded. (3) The mechanical controls for starting and stopping both slicing machine conveyors and wrapping machines shall be so located that the operator can control both units from one point. Controls shall be provided wherever necessary but there should be only one starting station so designed that

accidental starting cannot occur. The electrical control station for starting and stopping the electric motor driving the wrapping machine and conveyor should be located near the clutch starting lever. The transfer chain shall be completely covered on all sides.

With respect to wrappers, the Code provides the following: (1) Any hand wheel provided for turning the wrapping machine over by hand shall be of the smooth, solid disk type. (2) At the discharge end of the cross-feed conveyor, there shall be an appropriate guard in front of the cross-feed chain. (3) Electrical heaters on wrappers shall be protected by a properly insulated cover plate to prevent burns in case of accidental contact with the cover plate by the operator. A pilot light for indicating when the heaters are in service shall be provided. (4) Heat-resistant type of wiring shall be used for connecting the movable heaters to the permanent wiring of the machine. (5) Power-driven friction rollers used to feed paper into the wrapping machine shall be provided with a guard over the in-running nip point of the rubber rollers. (6) The nip point, between the chain and sprocket of the loose wrap attachment, shall be completely enclosed. (7) Sprocket, chain, and V-belt drives on wrappers shall be completely enclosed.

MISCELLANEOUS EQUIPMENT

In addition to the standard equipment described thus far, bakers make use of considerable auxiliary machinery and devices, such as emulsifiers, water meters, dough troughs, trough hoists, pan greasing and washing machines, rack washers, dough retarder boxes, low temperature storage cabinets, automatic bun machines, bun slicers, doughnut frying machines, icing machines, and others. Some of these units will be briefly discussed in the following paragraphs.

Automatic Water Meters. The correct measurement of properly tempered water for use in dough formation is a prerequisite to adequate control in mixing operations. Modern automatic water meters and blenders perform this function efficiently and have largely replaced the weighing tanks formerly used. The meters are equipped with dial indicators which are hand set for any desired weight of water up to 500 lbs. The inlet valve closes automatically when the indicated weight of water has passed through the meter. Most meters are also equipped with a mixing valve which permits the blending of hot and cold water, the proportions being regulated by a thermostat, to yield water at any desired temperature. By-pass faucets allow the drawing off of water in either indicated or non-indicated amounts. Depending upon inlet pipe diameters and water pressure, water meters will deliver from 200 to 450 lbs. of properly tempered water per minute.

Emulsifiers. Various types of mechanical emulsifiers and homogenizers designed to produce finely dispersed suspensions or emulsions of the small dough ingredients are finding application in bakeries. Originally introduced chiefly for the purpose of improving bread texture by bringing about complete emulsification of the small ingredients, and thereby assuring their uniform distribution in the dough mass, their use today is based also on considerations of sanitation and convenience. Made of

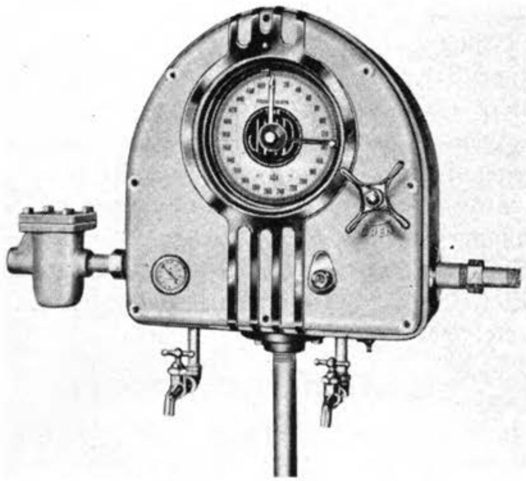


FIG. 165—Meter for measuring and tempering dough ingredient water. (*Courtesy J. H. Day Co.*)

stainless steel, and equipped with sanitary fittings and pumps and fine-meshed strainers, these units go far in providing final protection against the inadvertent admixture of foreign matter into the dough. Emulsifiers range in design from simple enclosed tanks equipped with propeller type agitators to high-pressure, dairy-type homogenizers. The use of the latter type equipment in bakeries is difficult to justify when relating the results obtained in terms of quality improvement with the initial and operating costs of these units. Generally, emulsifiers with a tank capacity sufficient to hold the entire ingredient water of a sponge or dough and equipped with a pump for transferring the emulsion directly to the mixer will be found most convenient. In normal operation, the dough water is run into the emulsifier tank from the water meter, the measured ingredients, excepting the shortening, are added and the impeller or agitator motor started. Emulsification should be completed within two to three minutes, after which the emulsion is ready for pumping into the mixer. The unit should preferably have its tank insulated to prevent exterior

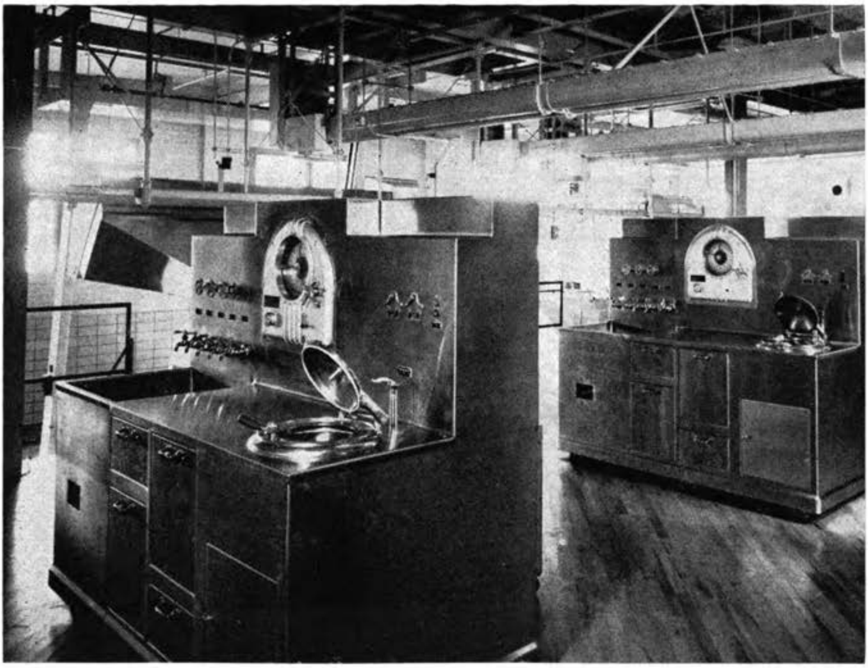


FIG. 166—Special water control units combining water metering, tempering and yeast emulsifying functions. (*Courtesy Helms Bakeries.*)

moisture condensation and also to permit holding the emulsion in the tank for several hours, if necessary, without causing it to warm up.

Troughs. Dough troughs, in common with all other types of bakery equipment, have undergone frequent redesigning and modifications until there is little resemblance between the modern trough made of steel and the old wooden trough. Except for use in baking plants equipped with a trolley system in which the troughs ride suspended from overhead rails, dough troughs should be mounted on anti-friction bearing casters to facilitate their movement by the operator. Constructed of stainless steel or stainless-clad steel, modern troughs feature finished edges, rolled top rim, sanitary caster shoes, unusual durability, and a multiplicity of design to meet individual production requirements. They range in their cross-sectional dimension from a minimum capacity of about 3 cu. ft. to approximately 7 cu. ft. per lineal foot, and in their length from some 4 to more than 12 feet. Among common trough types are: Standard troughs in which all four sides are permanently secured; the drop-side troughs with relatively high sides in which one longitudinal side is hinged at standard trough level, permitting the upper hinged section to drop outward; slide end troughs in which one of the end walls can be removed for

trough emptying; end-gate troughs in which one of the ends is provided with a hinged lower section which can be opened for dough discharge; rack end troughs in which one end wall can be raised for dough discharge by a gear mechanism actuated by a pully chain; chute end troughs in which the lower section of one end wall opens outward, providing an ab-

FIG. 167—Elevator-type hoist (right) raises dough trough into dumping position above divider. (*Courtesy Burny Bros. Bakeries.*)

breviated chute for dough discharge; slide bottom troughs in which a bottom panel is removed for trough emptying; and sloping bottom troughs equipped with an end gate.

The transfer of the sponge into the dough mixer or of the dough into the divider hopper may be accomplished either manually, by cutting the dough mass into smaller portions and throwing them into the mixer or hopper, or mechanically, by elevating the trough to a level above the infeed point of either unit and letting the sponge or dough flow into the mixer bowl or divider hopper by gravity. In bakeries in which the fermentation room is located directly above the make-up department, tilting troughs are normally used which deposit the sponge into a floor chute feeding into the divider hopper below. Otherwise, various types of hoist equipment may be applied. These include overhead hoists, hydraulic

floor lifts, elevator hoists and cradle type hoists. Overhead hoists make use of steel cables by which the trough is raised, the cables being actuated by motors. Since the hoist assembly is mounted on overhead tracks, it can be arranged to serve any number of mixers and dividers. Either chute end or rack end troughs may be used with the overhead hoist. The hydraulic floor lift resembles the single ram hoist used in automobile service stations. It is ideal for plants with limited overhead room. Since it is permanently located, it can service only one unit. Either chute end or rack end troughs are used with it but the trough must be equipped with a special bottom lift plate. The elevator type hoist raises the trough in a level position between two upright and slightly inclined members until the dumping position is reached when the trough is tilted sideways to dump the sponge into a special chute feeding into the mixing bowl. The cradle type hoist consists of two sturdy end columns—one of which houses the drive mechanism—supporting the main drive shaft from which are suspended the lifting arms with the trough cradle. Here the trough is rolled into position onto the cradle and is then lifted up and over in a semi-circular path, imparting a tilted position to the trough at the discharge point. A special chute directs the flow of the sponge or dough into the receiving unit.

BAKE PANS

Bake pans may differ widely in the baking performance they yield, depending on the material from which they are made and on the care with which their baking surface is maintained. Different pan materials vary in their durability, tensile strength, heat transmission and other properties and therefore may be expected to produce different baking results. Because of the close relationship between the bake pan and the crust color, flavor and uniformity of the baked product, the selection, treatment and general handling of pans deserve considerably greater attention than most bakers are inclined to devote to them.

The materials commonly used in the fabrication of bake pans include black iron, tinplate, aluminum, aluminized steel, and stainless steel (*238*). Each of these materials possesses a certain degree of proven suitability, although some have gained wider use and acceptance than others. The first pans used in commercial baking were made of simple sheet iron which readily lent itself to fabrication into the desired pan shapes. These sheet iron pans, however, possessed a marked tendency toward destructive corrosion which greatly reduced their useful life and necessitated almost daily cleaning. The first major improvement came with the introduction of so-called black iron or Russian iron, a sheet metal which acquired a black oxide coating of considerable rust resistance. Black

iron pans, because of their high heat conduction, gave excellent baking results, and for this reason are still used by some bakers to this day. However, their surface oxide film is subject to easy damage, with the exposed metal showing a high rate of corrosion, so that extreme care is required in their handling. They must, therefore, be kept well greased and dry at all times.

The outstanding development in bake pan fabrication came with the introduction of tin-coated steel sheet, or tinplate, as a pan material. Tinplate used for bake pans consists of special steel of proper ductility and tensile strength, rolled into uniformly thin sheets which are then dipped into pure molten tin to yield a coating about 1/10,000 inch thick. Pans made from such tinplate are sturdy and durable and, with proper care, should give satisfactory service for three years or longer.

New tinplate pans require both a washing and "burning out" treatment prior to their first use. The bright shiny surface of these pans reflects too much heat to give satisfactory baking performance and must first be provided with a dark oxide coating. This is accomplished by placing the washed and dried empty pans into the oven and heating them for approximately three hours at a temperature ranging from 400° to 425° F. until their surfaces assume a dark and bluish cast. The pans are then removed, cooled, and are ready for greasing or glazing. Care must be taken not to have the oven temperature exceed 425° F., since pure tin melts at 450° F. and impurities in the tin might lower its melting point (*239*). The tin might soften on excessively heated pans to a point where it will run and form beads, imparting a rough surface to the pan. Burning out, in addition to creating an oxide film, also acts to secure a better bond between the tin layer and the steel base by reacting the iron and tin to form an alloy, thereby minimizing the possibility of the tin flaking off because of different expansion rates of the steel and tin when heated. More recently pan manufacturers have adopted the practice of coating new tinplate pans with lacquers to simulate the surface character of burnt-out pans. This temporary coating permits the immediate use of the pans and is retained until an oxide film is formed on the pan surfaces during normal baking use. Mild detergents, rather than the usual caustic cleaners, must be used in the initial washing of the pans in order not to remove the lacquer coating.

Aluminum as a bake pan material has gained considerable acceptance, especially in the cake and pie bakeries, because of its superior heat conduction, light weight, and high corrosion resistance. The metal's chief drawbacks are its high cost as compared with tinplate and the ease with which it dents. In an effort to overcome the latter shortcoming on the one hand, and to retain the advantages of the aluminum surface on the

other, so-called aluminized steel has been developed (*240*). This material is similar to tinplate in that it is a coated-type product, but with the surface coating consisting of aluminum instead of tin. Stainless steel has also been tried as a pan material on a relatively modest scale. Its advantages of greater strength and superior corrosion resistance are counterbalanced by a relatively low heat conduction and higher cost.

Advances in the development of pan materials have been paralleled by correspondingly important progress in the design and fabrication of pans, the aim always being to incorporate features in pans which will facilitate the production of uniformly shaped loaves and other goods. Thus, for example, the use of three or four small perforations in the bottom of the pans permits the release of air and steam pockets and thereby prevents the development of hollow or cupped loaf bottoms. The occurrence of cupped bottoms may also be counteracted by the use of convex pans, in which a slight convex curvature of the pan bottom is a special feature of the pan design. The curvature amounts to a maximum of $\frac{1}{4}$ inch in the center of the pan and frequently the ends of the pan are also provided with a very slight outward curvature. In the baked loaf, these outward bulges at the bottom and the ends disappear on cooling, leaving perfectly flat surfaces which greatly facilitate wrapping operations. However, pans with the convex design require special care in handling so as not to dent them, since in that case the pan bottom tends to spread, yielding misshapen loaves. Another relatively recent feature of bake pans is their provision with button bottoms to assist in the elimination of scorched loaf bottoms. These buttons represent outward depressions measuring about $\frac{1}{16}$ of an inch in depth whose purpose it is to prevent direct contact of any part of the pan bottom with the hearth. By providing a slight elevation, free heat circulation under the pan is insured which results in a uniform bake and crust color. This feature achieves its particular usefulness in the case of older pans which have sustained slight dents in the course of rough handling. It is at the outward dents that localized heat spots develop and lead to excessive darkening of the crust. Grid-type baking trays and ovens in which adequate bottom heat represents a problem will not accommodate button bottoms to advantage.

Bread pans are normally strapped into sets of three or four pans by means of metal bands. The optimum distance between the pans within a set is predetermined and permanently fixed. The spacing between pan sets, however, may vary considerably, depending upon the skill of the oven man. To prevent too close spacing of the pan sets, spacer lugs are attached to the strapping side bands and end strips which, when the sets are pushed tightly against each other during oven loading, will provide the same amount of spacing between the sets as exists between the

pans within the individual sets. This feature contributes to uniform baking.

Baking pans require periodic cleaning for three general reasons: (1) to maintain their efficiency of performance; (2) to prevent the occurrence of off-tastes in baked products; and (3) to prolong the useful life of the pans. Clean pans conduct heat more uniformly and completely, seldom attaining a temperature in excess of 270° F. during baking (*241*). Pans in which carbonized grease has been permitted to accumulate and act as an insulant may, on the other hand, reach a temperature as high as 420° F. at which point the stale grease rapidly attacks the burnt-out surface and the underlying tin. Bread pans should be washed by the soaker tank method after 100 to 150 bakings to prevent the occurrence of rancidity.

The material that adheres to pans after use consists chiefly of baked-on sugar, fat, grease, masses of protein from flour, eggs and milk, and, in the case of pie pans, caramel and fruit acids as well. Since plain water will not effectively remove this material, properly selected detergents must be used. Such detergents, to be satisfactory, must provide rapid action, thoroughness of cleansing, and a minimum of damage to the pan materials. The functions required of an acceptable detergent in the case of mechanical pan washing have been outlined by Rumsey and Strong (*242*) as follows:

(1) It must soften hard waters by precipitation of the water hardening salts to facilitate the saponification of fats and to prevent film formation on the pans. (2) Fats and grease must be saponified to change them from an insoluble to a soluble form. (3) The interfacial tension between water and oil must be reduced to facilitate emulsification. (4) Oil must be emulsified and dispersed through the water for easy removal by the sprays. (5) The detergent must rinse off easily to prevent subsequent corrosion of the pan material. (6) The pH value of a 0.1 percent solution of the detergent must be higher than 10 and lower than 12 to prevent attack of the metal of the pans. In the case of pan washing by means of soaker tanks, the detergent must also possess the ability to solubilize proteins and to flocculate them to facilitate protein removal.

While it is possible for bakers to compound their own detergent solutions from the various chemicals, it will generally be found better practice to select one of the many commercially available compounds possessing the right combination of properties. Such detergents should consist largely of soda ash and tri-sodium phosphate, modified with other chemicals to act as buffers, to assist in softening water, to regulate alkalinity, and to protect metals from corrosion.

Experience has shown that the best pH level of the detergent solution is 11.2, although good results are obtained with a range of 10.6 to 11.5. To keep within this rather narrow range, the solution should be tested frequently. This may be done readily by means of phenolphthalein test paper provided specially for this purpose. More accurate control is obtained by determining the pH with a standard pH meter in the laboratory. The alkalinity of the solution should also be frequently tested by titration. Depending upon conditions, a pH of 11.2 should be obtained with an alkalinity lying between 0.05 and 0.1 percent with respect to caustic soda. An alkalinity of 0.2 percent should never be exceeded, otherwise corrosion will result. The strength of the solution is preferably maintained by an automatic feeder which will add the detergent continuously at a predetermined rate while the machine is in operation and thereby avoid marked fluctuations in strength. Automatic temperature control should also be provided. For best results, the temperature of the wash water should be maintained at 140° F. and of the rinse water above 170° F.

Pan washing equipment of different designs and capacities are available. They provide for soaking of the pans in special detergent solutions at elevated temperatures which are attained by means of either closed or open steam coils, followed by rinsing by jet sprays. Pans are immersed in and lifted out of the solution stacked in baskets which are carried by an electrical hoist.

Racks and Trucks: Except in completely mechanized bakery plants in which practically all movement of semi-finished and finished products is by means of power-driven conveyors, the rack is the most widely employed carrier of pans, panned dough, and finished baked products. Made of metal and mounted on casters or provided with trolleys for use on overhead rail systems, modern racks are characterized by sturdy construction, ease of handling, adjustable shelves, and long service life. To reduce the great variability in height, width and other design features which have marked bread and pan racks and pan trucks made by different manufacturers, the Standardization Committee of the American Society of Bakery Engineers, in its report for 1948 (*243*) has recommended the following standards for bread racks: The rack is to consist of 9 shelves with a clearance of 6¼ inches between the shelves. The shelves should be 28″ wide and 66″ long, and be built of four 1″ × ⅛″ bars, equally spaced running lengthwise, with bars of the same strength on each end. The supporting wiring should consist of No. 9 wire, spaced equally 1″ apart. The racks should be equipped with casters of 5″ diameter, with wheel bearings of the roller type and swivel bearings of the double

ball type. All casters are to be equipped with pressure type fittings for greasing. The specifications for pan racks are the same as for bread racks, except that 10 shelves are to be used with a clearance between the shelves of 5¾ inches instead of 6¼ inches.

The specifications for pan trucks are as follows: The truck deck should be of solid steel or aluminum of 10 gauge thickness and should have a floor clearance of 13 inches. Deck sizes are to be 24, 30, or 34 inches wide and 48, 60, or 72 inches long. The truck handles are to be on the end on which the swivel casters are located. The wheels are to be two 6 inch swivel casters with roller and ball bearings and two 12 inch wheels on a rigid axle with roller bearings. All wheels are to be equipped with pressure type fittings.

Safety standards of the American Standards Assoc. (*230*) for racks include the following provisions: racks should be free of sharp splintered or rough corners and edges; rack handles shall be so located with reference to the frame of the rack that no part of the operator's hands holding onto the handles shall extend beyond the outer edge of the frame; casters should be of the anti-friction type of facilitate control of the racks; proofing racks should be provided with end guards at shelf levels and, where proof-box construction permits, corner bumpers should be installed on all four corners of the rack giving a two inch clearance.

EQUIPMENT DEPRECIATION

All equipment that is in constant use undergoes deterioration. Moving parts of mechanisms wear out, surfaces erode or are damaged through accident or carelessness, machinery is at times operated in excess of rated capacity, etc. Even under ideal conditions of care and maintenance, a certain degree of natural wear and tear takes place. The U. S. Bureau of Internal Revenue has published for accounting purposes a schedule of allowable depreciation rates at which a baker may write off his investment in equipment. These rates are based on the average useful life of each unit of equipment, the average having been presumably obtained by a study of equipment deterioration encountered in actual practice under normal operating conditions. It should be pointed out that full depreciation after the indicated period is in many cases of theoretical significance only since much equipment continues to give excellent service beyond its rated useful life. On the other hand, some equipment may under careless or inexpert handling have reached complete obsolescence years before the termination of its allocated period of usefulness. The following schedules are based on "Bulletin 'F' (Revised) Income Tax Depreciation and Obsolescence—Estimated Useful Lives and Depreciation Rates" issued by the U. S. Bureau of Internal Revenue.

BAKERIES

In general, it has been found that the composite life of 12½ years applies to cake bakeries, 14 years to bread bakeries, and 20 years to biscuit manufacturers. The item lives applicable to the baking industry are set forth in the following tabulation, some adjustment being needed, depending upon the type of bakery in which the assets are used:

Average useful life (years)

Ballers, dough	15
Beaters:	
Light	10
Heavy	15
Bins, flour storage:	
Steel	33
Wood	25
Brakes, dough	15
Burners, gas or oil	15
Cake machine, open saddle	20
Case for shipping bread (inventory)	2
Cleaners, sack	15
Coating machines	20
Conveyors:	
Belt	17
Chain and flight, cake	20
Panning	20
Slat apron bread	25
Spiral screw	25
Cookers, doughnut	15
Cookie machines, wire cut	17
Cooling equipment	20
Cooler and packer	15
Cracker cutting machines	15
Cracker peeling machines	15
Cracker machines	15
Cutter—wafer	15
Cutting and panning machines	25
Depositors—cake	15
Dies, rolls, and cutters	10
Dividers—dough:	
Hand	20
Power	12
Doughnut machines, automatic	15
Droppers:	
Cake	15
Cookie	20
Dryers, special cookie	20
Elevators, flour bucket, or pan and tray	20
Elongator	20
Embossing machine, biscuit	20
Enrober	20
Fans	15
Forming and stitching machines, carton	15
Fruitana machines	20
Gluing machine	15
Grinding machines	15
Humidifiers	15
Ice boxes	15
Icing unit	15
Kettles-copper jacketed:	
Chocolate melting	25
Marshmallow	15
Mixers:	
Cookie and cake, three spindle	25
Dough, five barrel:	
High speed	20
Slow speed	25
Vertical dough, three and four speed:	
Light	15
Heavy	20
Moulders:	
Dough	12
Roll	12
Ovens:	
Automatic or traveling	17
Band type	20
Brick peel	20
Portable peel	20
Reel	20
Rotary	15
Stationary	25
Packers	15
Pan greasers and cleaners	10
Pans—baking	6
Paring machines	10
Peeling machines	15
Perforating machines	15
Pie crimpers and trimmers	15
Pie rolling machines	15
Pretzel cooking machines	10
Proofers	15
Pulverizers, sugar	20

Average useful life (years)—Continued

Reels, bolting	15
Refining machines, chocolate	20
Refrigerators	15
Roller, pie crust	15
Rounding machine, dough	15
Rubbing and creaming machines	20
Sack cleaners	15
Sandwich machine	15
Scales, automatic—flour or water	15
Sealer	15
Sheeters	15
Sifters, flour, sugar, starch, etc.	17
Slicers, bread	12
Spreader, sugar wafer	20
Tables, sorting	20
Tanks:	
Galvanized iron	15
Glass, enamel lined	25
Steel	25
Tempering and measuring	15
Wood	15
Tape moistening machine	15
Thermometers:	
Mercury column	5
Recording	10
Topping machines	20
Troughs, dough	25
Trucks, bowl, bread or pan	20
Wafer machines, automatic	20
Wrapping machines	15

MOTOR AND OTHER VEHICLES

Motor vehicles included in this classification are those used by commercial enterprises other than public utility and construction. Lives considered reasonable are indicated below:

	Years
Automobiles:	
Passenger	5
Salesman	3
Horse-drawn vehicles	8
Motorcycles	4
Tractors	6
Trailers	6
Trucks:	
Outside use:	
Electric	10
Gas, light	4
Medium	6
Heavy	8
Inside use	15

CHAPTER XXX

BAKERY SANITATION

By DR. EDWARD L. HOLMES
American Institute of Baking

A vital problem for every baker today is that of sanitary operation of the bakery. The Mid-Twentieth Century American public is very sanitation conscious and has come to associate its well-being and good health with the maintenance of the highest standards of cleanliness in any process related to food manufacture.

The housewife spends most of her working day in her kitchen, hence she believes it must be maintained under ideal conditions. Perhaps some of the best looking kitchens of today are not always truly sanitary but the housewife thinks so and she expects any establishment from which she purchases manufactured food to be maintained on a similar basis.

This means that a baker, insofar as he is able to do so, must maintain his premises in as spotlessly clean a condition as the frequently observed advertisements of the modern, supposedly-clean kitchen so that any housewife, who by chance may visit the plant, will be suitably impressed.

In addition, any one purchasing bakery products today expects to find them totally free from foreign matter. This places a second burden upon bakery sanitation, for it is quite possible for the baker, or the housewife herself, to have a perfectly clean looking establishment and, at the same time, unknowingly use infested ingredients or infested equipment which might contribute extraneous matter to the finished products of even the best looking kitchen or bakery.

In other words, today's baker must not only have a clean looking establishment but he must produce products totally free from extraneous matter. Bakery sanitation is not concerned entirely with this extraneous matter, but it must be recognized that its presence in bakery products will certainly be considered as a sign or index of a dirty condition in the plant in which the products are manufactured.

The first responsibility in any program of bakery sanitation falls upon management. The manager and owners of the bakery must understand what is expected of them in sanitation. Then, they must understand what is required of them to realize this expectation and, third, they must

expend the necessary effort and provide enough money to actually accomplish it.

In the small space allotted for this chapter, it will not be possible to do much more than attempt to impart such an understanding to the reader. There are many sources of information for the ultimate details of the means of accomplishment of the objectives outlined here. For example, the baking industry of the United States, through the American Institute of Baking, has developed a sanitation department expressly for the purpose of developing the facts and disseminating information about sanitation to bakers throughout the country. There are many private consultants who attempt to do the same: some very successfully. It is virtually impossible for a bakery manager to know everything that he should know about bakery sanitation "just out of the air" or to learn them from salesmen of sanitation supplies and equipment. It is urged strongly that anyone operating a bakery, who has not set up a sanitation program, should undertake to obtain really expert-scientific advice in his initial effort lest he waste money and time uselessly on worthless practices.

One of the chief reasons that so many bakers have had trouble in the field of bakery sanitation is due to the fact that they got off to a bad start with false information. In this chapter, a basic sanitation program for the reader's general guidance will be developed in outline form to aid him in keeping from doing so.

First of all the bakery manager must recognize that he has three fundamental parts to his sanitation program:

(1) The development of a planned program of supervision for cleaning operations so designed as to keep the bakery as clean as a modern home kitchen;

(2) The development of a planned program to check ingredients and hidden places in equipment and building structure for possible insect and rodent infestation which might furnish extraneous matter to the finished product;

(3) Third, he must make a study of the practices of all plant employees when handling the product after baking, lest food-handling practices be developed that might result in isolated or mass food poisoning of consumers.

Note that these three parts of the program are described as associated with the development of a plan. Most bakers recognize the three factors but they have not recognized that they cannot achieve correction of undesirable situations without a carefully planned program.

A sanitation program will have to vary according to the size of the bakery. Let us outline very briefly what many large companies have

come to consider the basic foundation of their sanitation program and from that the small baker can adapt as he sees fit.

First of all, every bakery must have a sanitarian. This individual can hold a full-time job devoted entirely to sanitation, or part of his time may be devoted to it. However, sufficient time must be allotted for the sanitation features of his work: it is not to be considered a spare-time or sideline occupation. Many bakeries appoint the production superintendent or the plant engineer as the sanitarian without giving him sufficient relief from his original duties to enable him to give serious consideration to sanitation. The net result is that sanitation suffers and there is really no program. The very best solution to this problem has been found in the assignment of one individual as a full-time sanitarian with direct responsibility to the plant manager: *not under one of the key superintendents of production or engineering.* The sanitarian must not be classified any lower than a second-grade official of the plant, for then he cannot cope with the problems of cooperation, which will be discussed later.

In order to assist the sanitarian in carrying out and developing his program, a *sanitation committee* should be set up within the plant. This should consist of the manager; the sanitarian, who will serve as secretary; the production superintendent; the chief engineer; and the foremen of such portions of the plant as are deemed best, these serving in rotation so that every key employee in the bakery will at some time or other have a chance to serve on the sanitation committee.

This committee should meet once a week and discuss sanitation problems within the plant for a half hour, tabling, at the conclusion of that time, any discussions underway until the next meeting. This is an important point of procedure for, if the meetings are allowed to be protracted, they will develop into nothing more than a debating society of doubtful accomplishment. Further, no bakery can really spare the time of key employees for much more than a half hour a week.

Another fundamental feature of the sanitation program is the development of a routine inspection procedure by members of the sanitation committee and those designated by it. This inspection program must be so designed that individuals make a detailed inspection of every part of the bakery about once a month. If it is a large bakery the inspections may take place once a week, covering perhaps a quarter of the bakery during any one given week. The inspections are not to be made by the sanitarian, solely, but by him in the company of other members of the staff of the bakery, whose viewpoints will materially aid him in uncovering undesirable features.

Such basic organization for carrying out the program may seem cumbersome and unnecessary until it has been tried; but, it has worked and

is actually being followed in a great many bakeries today. Granted, most of the bakeries using this system of organization have large plants, but it can be adapted in a modified form by even the smallest bakery. In a small retail shop, for example, the manager's wife would make an excellent sanitarian and the manager and his wife together a sanitation committee. An inspection program can be set up during alternate weeks, each one to comment on conditions in the light of what was found by the other the preceding week.

Cleaning Program. After a plan of supervision has been set up, a plan should be developed for all cleaning procedures.

Definite schedules should be set up listing all daily cleaning jobs, all weekly cleaning jobs and all less frequent cleaning jobs. In a very large bakery, employing a number of porters or janitors, these jobs should be divided equally and assigned to specific individuals among whom they can be rotated from time to time so that each porter becomes familiar with all jobs. This is especially important where there is any turnover of personnel.

Management must also plan for the provision of adequate cleaning tools and proper apparatus for the application of insecticides and control of rodents.

There must also be a consciousness of the need for cooperation between different departments of the bakery if the plant is large enough to be departmentalized. Many insanitary conditions in a bakery result from lack of this cooperation. For example, in many instances the engineering department undertakes repairs at a time when there are normally no janitors to clean up after it. Intelligent cooperation would involve planning between departments in such a way that the janitor crew will be available to clean up the bakery and have it in perfect order for production just as soon as the engineer crew is done. There are many other instances that could be cited which will undoubtedly occur to every reader.

Last, but not least, there must be a consciousness of the need for constant training of janitors, porters and production workers in better individual understanding of sanitation so that they will do a better job of cleaning, in the case of janitors or porters; and a better job of preventing the development of insanitary conditions, in the case of production workers.

It is necessary for the plant's general manager to understand thoroughly every aspect of sanitation in order to appreciate the need and amount of training required, for such training crosses the borders between departments. Oftentimes it will involve controversy with union leaders relative to assignment of cleaning responsibilities. It is certainly man-

agement's function to guide and plan this training, although the details of it may be carried out by the sanitarian and various department heads.

Preventive Sanitation Practice. We have all heard of preventive medicine, which consists of treatment to prevent the development of functional disease before actual disorders occur. Today we are hearing of preventive maintenance, which means proper periodic maintenance of equipment so that it will not break down. In the field of bakery sanitation, preventive sanitation is unquestionably the most valuable aspect of that subject. It is an effort to prevent the development of insanitary conditions through maintenance of as high a degree of cleanliness as is possible at all times. Cleanliness in this regard, however, does not consist merely of cleanliness as to appearance, but also cleanliness in the removal of all possibilities for the development of infestations of insects and rodents.

A good preventive sanitation program centers upon a good program for building-structure maintenance, equipment maintenance, maintenance of housekeeping and orderliness in the plant's work operations and in proper inspection and storage of ingredients. If a suitable program is set up with a view to the possibility of development of insanitary conditions for each of these items, then there need be few problems for such a plant in its over-all sanitation.

This statement is made with a full realization that many bakers think that bakery sanitation is primarily concerned with the use of insecticides, rodenticides and disinfectants. This is emphatically not the case: no bakery has a good sanitation program if it has an urgent need for the application of any of these substances. These materials have a use in the bakery but they are needed only as secondary tools in the control of insanitary conditions. They are guarantees rather than an instrument in themselves for achieving sanitation.

As bakers, plant operators will not be told of this fact by distributors of such products and that is why it is so necessary for plant owners and managers to appreciate for themselves the true meaning of bakery sanitation and the extent to which it enters into plant operation.

In years gone by when regulatory officials visited a bakery and informed a manager that his plant had a serious insect infestation, the only recourse at hand for him was to call in a representative of some insecticide house and ask him for a spray recommendation. As a result of this practice, over the years many bakeries bought more and more insecticide and more and more complicated installations for applying it. At the same time, however, infestation continued in such plants: no study was made as to what was causing the insect infestation and no effort was made to remove the cause, rather than the result.

Preventive sanitation measures, however, are concerned with the maintenance of a minimum rodent and insect infestation before chemical preparations are ever used for the control of casual invading pests. At first the cost of such preventive sanitation measures may seem exacting; however, in the long run the savings derived in the reduction of use of ineffective proprietary preparations will probably more than offset the effort and money expended in the initial serious endeavor.

Let us consider briefly what such essential measures in any preventive sanitation program are.

Building Structure and Storage. The two basic problems that first beset the baker in developing a sanitary plant are the elimination of the possibility of rodent and insect infestations. To do this, first, the plant must be made rodent-proof to prevent rats from getting into the plant from any outside source. The few shortsighted bakers expressing the opinion that it is bad public relations to admit that a bakery may become rat infested do not take into consideration the fact that a bakery is probably as close an approach to "rat heaven" as any industrial establishment. Its normal conditions of warmth, moisture, food supply and various nooks and crannies in which an invading rat can hide without difficulty—unless the baker makes special effort to eliminate these latter—create such a desirable environment. Rat-proofing the plant requires some skill, possibly outside assistance, or at least a thorough study of the problem and details of the measures to be employed must be made. There is no possibility of covering such a subject completely in this brief chapter, so it will be left with the simple statement that the plant must be rat-proofed so that no rats can enter it. This means that all entrances to the outside must be less than 3/8 of an inch across and constant watch must be kept to make sure that new "avenues of entry" are not made by careless installation of pipes through walls and the like, after the building is built.

It will be noted that no effort is made here to mention mouse-proofing a plant: *This is virtually impossible*, and really not necessary except in extreme circumstances where it is well known that mice are traveling regularly back and forth from the outside through some regular route. Mouse-proofing a plant would mean that all communication from the outside must be closed so that there is no orifice greater than 1/4 of an inch in diameter.

Rats will invade a bakery on their own feet from the outside if they can find a hole through which to get in. Mice, on the other hand, invariably come into a plant "on the backs of men." They come in, almost always, with ingredients or cartons and, occasionally, in empty bread

trays. They are carried in and when they gain entrance seek some place to hide, or what is called a harborage.

It is necessary, therefore, to eliminate all mouse harborages within the plant. These are simply places where mice may nest undisturbed. They may be in stored materials that are left standing for long periods of time, in hollow spaces in walls, between floors and ceilings, underneath raised platforms and the like. All such spaces must be opened so that they may be inspected readily and cleaned frequently.

Storage must be moved at intervals of every three weeks: This applies to storage of old and unused equipment as well as to ingredients, paper stock and the like. It is granted that such a requirement probably means that unused and old equipment cannot be stored in a bakery safely. It is really necessary to get it out of the plant unless it can be cleaned thoroughly and moved every three weeks.

In regard to insect infestation, there are two types which beset the bakery. One, a class of insects that enter the plant in a manner very comparable to the means of entrance of mice. These insects are cockroaches, silverfish and the like, which come in with incoming ingredients, cartons, paper stock or empty bread trays. It is virtually impossible to eliminate harborages for these insects for they require so little. However, all large areas can be sealed off from access from within the bakery —for example, unexcavated portions of the basement—or else treated with powerful insecticidal remedies such as the residual deposits that will be discussed later. Silverfish usually frequent the area around the ovens and other warm places in the plant and residual deposits can be applied to catch these as they arrive from the outside, before they have a chance to multiply in the plant.

Other types of insects fly into the plant. These will set up breeding places wherever they can find food. Almost invariably, where serious infestations of flying insects have been found in the plant they have been found breeding within the building itself. This applies to flies, moths and the like. Occasionally, insects normally living outdoors will invade the plant during the height of the season. These are such night-flying insects as crickets, leafhoppers, night moths, etc. They cannot be controlled very easily, except by screens, but their attack is mostly seasonal.

Where there is a large fly or moth infestation, the breeding place must be found either within the plant itself or closely adjacent to it on the outside. Many bakers believe that flies are constantly hovering about on the outside trying to enter their plant and that there is nothing they can do about them except to put up an intricate system of screens. Modern-day students of fly control have come to the conclusion that more flies

may be kept within an industrial establishment by screens than are kept out. For example, in the past year the writer has found large fly populations in bakeries resulting from dirty brushes thrown on the top of an oven on which there was a lot of nutrient material which was found to be supporting fly-maggot colonies. Putrifying masses of ingredients that had seeped into the bases of mixers, putrifying material at the bottom of scale pits, putrifying material in improperly flushed and cleaned drains and the like have been found in plants that were well screened. In each instance a few flies had obtained entry from the outside—as will always be the case—found a place to breed and large colonies had resulted. Again, fly colonies have been found just outside of plants, resulting from poor disposal of garbage. One bakery in particular has a program of spraying heavily for flies inside the plant on Saturdays. This spraying is effective and probably kills all of the flies within the plant but, gradually, during the following six days, more and more flies appear which come from breeding grounds just outside, where the plant's garbage is improperly disposed of. Much nutrient material has soaked into the ground in this area, in cracks in the concrete, and so on, so as to serve as a good breeding spot for flies. Even the interiors of garbage cans will breed flies if not properly flushed.

Again summarizing what is meant by preventive sanitation, it must be recognized that insects and rodents require food, water and shelter in which to live. The major purpose of preventive sanitation measures is to eliminate harborages or shelter, cut down on the materials that might serve as food and, wherever possible, keep the moisture low in order to prevent the development of infestations of rodents and structural and flying insects.

There is one other aspect of preventive sanitation that is very important, and perhaps peculiar, to bakeries and, certainly, to any food-manufacturing establishment that uses finely ground ingredients such as flour. There are varieties of insects, mainly beetles but to some extent moths, which lay eggs in the grain from which flour is ground. In various ways these eggs may carry through to the finished product, no matter how much care is taken in manufacture. When a bakery handles flour by machinery, accumulations of flour which never move will develop, often called "dead" flour. In these accumulations of dead flour the eggs remaining therein eventually hatch and develop breeding infestations. There is no way to prevent this, other than by cleaning the equipment routinely once every three weeks, followed by spot fumigation, or local treatment, with special chemicals to such portions of the equipment as can be closed off airtight. This is especially important where it is not possible to clean the equipment absolutely from flour residues. Good

preventive sanitation requires that all flour-handling equipment, or other equipment designed to handle finely divided ingredients, must be cleanable to the extent that a vacuum cleaner can be utilized to take out all of the dead flour during the regular three-week cleaning interval. This may mean, if the baker has equipment that is not specifically designed for this purpose, that he must change its design by making cleaning ports in the equipment at the appropriate places. Modern manufacturers of bakery equipment are recognizing the need for cleaning equipment in modern bakery operations and are devising their new equipment accordingly. However, there is a great deal of old equipment which a baker may not be in a position to discard.

It is possible to rework practically any piece of old bakery flour-handling equipment so that it can be cleaned. The only exception is wooden equipment which has been tunneled by wood-boring insects such as the cadelle. In such a case, the panels already riddled must be replaced by new wood.

Any kind of damaged metal linings will either have to be replaced entirely or taken off. Many bakers today are removing metal linings of bins for this reason, as there is no better harborage for dead flour and insect infestation than the space between the lining and the wooden side of the bin.

Practically all the work discussed in this section must be planned by the bakery plant sanitarian. However, it will be noted that in this particular field of his work he will have to work in very close cooperation with the engineering department. Many bakeries have made the plant engineer the sanitarian as well, with the thought that this is the principal problem of plant sanitation. This is not necessarily true but it does mean that, where this dual assignment has been made, the engineer usually sees that the equipment and structure are in good shape for better sanitation. Where the engineer is not the sanitarian, then it would well behoove the plant sanitarian to get his viewpoint over to the engineering department and work in constant cooperation with it. In any event, the plant manager should exercise his supervisory abilities to the utmost to see that this is done. *There will never be a sanitary bakery where the sanitarian and engineer do not see eye to eye with regard to better maintenance and elimination of harborages and avenues of entry for rodents and insects, with redesigning of equipment for better cleaning wherever needed.*

Housekeeping and Orderliness. The production superintendent of the bakery has a heavy sanitation responsibility too, for he must learn to plan his work and supervise the activities of his employees in such a way that he does not produce undue insanitary conditions. If there was no production in a bakery it would be doubtful that the sanitation prob-

lem would be a very serious one for it is the by-products of bakery production that occasion the development of infestations.

Let us consider bakery sanitation aspects of production from the very beginning to the end. First of all, as incoming ingredients are received and taken into the storage warehouse they must be inspected for prevalence of insect infestation and rodent infestation. Whoever receives ingredients and puts them in storage should train his crews to look carefully at each container. Any that are damaged in any way should be set aside for careful examination later by the plant sanitarian. It may be that these will have rat gnawings, indicating some rodent boring, or, they may have cracked seams into which filth has penetrated, or any of a number of things: all meaning that the individual carton must be considered on its own merits and either discarded or partially recovered.

Examination of Incoming Flour. The principal problem here is the examination of flour for the possibility of infestation. An entire chapter could be written on this subject alone. Suffice it to say, however, that there must be a physical examination of the exterior of the bags as they are received to see if there are insects crawling about on them. A representative number of bags should be opened and examined by sifting through a hand sieve, probably containing a 30-mesh wire screen, to see if there are insects in the contents. Perhaps five pounds of flour from five to ten bags could be so examined to good advantage from every carload lot received. For less than carload lots, still five to ten bags should be examined. A baker having sufficient volume of receipts would do well to get a small portable mechanical flour sifter, to sift the entire content of bags. There are a number of these on the market and more are being designed so that they can be readily obtained at an early date. It is better to sift the contents of an entire bag if a power sifter is available for, all in all, what we are looking for is an infestation of one to four or five insects per bag, on the average. Usually, these live insects are found adjacent to the seams of the bag, hence it is perhaps possible to recover them by only removing a small part of the bag's content: but this is never a certainty. Flour containing more than one live insect per bag, on an average, should be refused.

Other ingredients should be examined as well. A representative number of cartons of raisins can be opened to see whether there are insect larvae at the top, close to the folds of the carton: there often are, for raisins are very susceptible to insect infestation. Dry milk, cocoa, chocolate, etc., are also susceptible, as are nut meats.

Storage of Ingredients. Good storage must be maintained at all times. Any product that can be kept at cold storage below 50° F. need

never develop insect infestation. However, mice have often been known to live in cold storages and feed upon cartons of nuts and raisins and the like stored therein. They sometimes nest in the cork insulation of the cold storage room.

Flour and other ingredients that are used in such bulk that they cannot be kept in cold storage must be stored in such a way that the entire storage facility can be inspected daily and turned over by restacking those not used each three weeks, or as close as possible to this interval. For large bakeries it is recommended that stacks be set up on skids, to be placed in groups of not more than four, with an aisle eighteen inches between so that a man can get between the stacks in order to inspect and clean them. The skids should be at least 10 inches above the floor.

Some very large bakeries are now using palletizing methods of receipt and storage. This presents a good many sanitation difficulties for, unless the material so stored is turned over very frequently, the method makes for a perfect rodent and insect harborage. This is true because such pallets for mechanical storage are not more than two inches above the ground and it is impossible to clean underneath them.

In a small bakery storage is usually not a problem unless the baker makes the mistake of leaving small portions of unused ingredients until they become insect infested. In fact the most frequent criticism that is offered the small baker for his sanitary practices is the tendency to hoard small batches of unused ingredients. Again and again infestations, such as moths, have been found in drums of molasses containing only a few pounds in the bottom of the drum. Small quantities of corn meal, rye or whole wheat flour are ingredients often tucked away only to develop infestations in them. The small baker should make it a point to keep his plant free from storage of any infestation-producing material other than what he is actually using. Neatness and orderliness in his storage practices will cut out at least half of his sanitation worries. Probably the greatest enemy of the small baker is the thought that he need have no such worry since he does not use large quantities of ingredients. This is granted as true, but too often he may leave remnants to cause trouble.

Flour Dust. One of the greatest problems of infestation by insects in a bakery centers about the accumulation of flour dust in the plant. This may be due to unnecessary spillage at time of dumping, with the accompanying blowing of dust throughout the bakery. It can be controlled, in some measure, without too great expense, by installing adequate force-draft ventilation by means of heavy fans. Such ventilation not only eliminates flour dust but makes the bakery a much pleasanter place to work in. However, all too often one sees a bakery with a rather elabo-

rate system of fans blowing air from the outside in, rather than blowing away from the flour-dumping points to the outside, which is the proper procedure.

It is possible, of course, too, to teach the individuals dumping flour not to make too much of a mess. Whenever flour is dumped the bag should always be brushed to insure that no material adhering to the bag is dumped with the flour.

Production Worker's Part in Sanitation. Very generally speaking, as a custom derived from the old trade guilds, it has always been a rule that every worker take care of his own tools of production. In a bakery, of course, the tools of production actually belong to the bakery and are not the worker's, as for example: the horizontal mixer, the large mechanical vertical mixer, the overhead proofer and the like. However, certain individual workers are assigned to use these tools and they are the men that should keep the areas of these machines which touch dough clean. In other words, the mixer man should be held responsible for the condition of his mixer when he turns it over to his successor or when he closes it down for the day. Where it has been found possible to hold production workers to this requirement in a bakery, sanitation has been materially improved, for production workers then learn not to make any more of a mess than is absolutely necessary. Everyone who has ever done any kind of work with his hands knows that if you tidy up and keep things clean as you go along there is much less final cleaning to be done and that the total actual time and effort spent on cleaning is materially less—for dirt breeds dirt.

Let us examine one or two possibilities here. Take, for example, a typical vertical mixer that has three speeds. If the production worker is taught that it is part of his duties to clean up any spillage from his mixer he will certainly take extra care not to place his ingredients in the mixer bowl in the wrong order and not to start the mixer at high speed, both of which are practices often resulting in splashing dough mix all over the wall and floor. It is best to start the mixer at low speed—as it should be done—and it is possible to add ingredients in such order that they do not splash. Development of an appreciation of such practices is the responsibility of the production superintendent in a bakery. In a small bakery, where the manager or proprietor may do much of his own work, the same principle holds.

There are several other practices that are of special value in maintaining sanitation through proper training of production workers. Workers must be taught to keep ingredient containers off the floor and covered, and to keep such cleaning tools as are set aside for their use readily available and properly stored. Equipment not in use should be kept properly

stored at all times so that it does not clutter the plant, thus leading to a disorderly condition. Everyone working in a bakery is familiar with the possibilities here. One of the most common situations is the practice of leaving beaters from the vertical mixer scattered about the plant after cleaning. Effort should be made to see if it will not be possible to set up an "A" rack on casters for the purpose of hanging the beaters so that they can be kept in orderly storage. A very great percentage of the disorderliness found in cake shops usually comes from spillage by people weaving in and out between unused mixer bowls or used mixer bowls waiting to be cleaned. Neat, orderly habits on the part of the mixer-hands in a cake shop result in practically no cleanup problems.

Again, it will be seen that in this field of endeavor there is a need for good cooperation between the production superintendent and the sanitarian. This statement is not reserved entirely for large bakeries. It is a good idea, even in a small plant where only one or two people work, for the manager to recognize that he has divided problems. Even if the manager is the principal baker he has a sphere of activity in which he acts as production superintendent of his small shop and in which he acts as the engineer of his shop. In all these activities he must learn to develop the sanitarian's viewpoint as well as to coordinate these three phases of his job personality. Any small baker successful in doing this will not have any sanitation problems.

Cleaning Programs. Regardless of the size of the bakery, any cleaning program must be planned. This program must provide for the daily cleaning of every food-product zone surface utilized in the bakery. This term, food-product zone, is applied to those areas of baking equipment that actually touch the ingredients, mixes and finished products. The bowls of mixers, spider, the mixer arm of vertical mixers, beaters, all must be cleaned daily after use. Utensils, work tables and any area where dough is worked must be cleaned daily and the floors must be cleared of spillage and cleaned free of any adhering dust or dough, even though this means mopping. There may be many other items requiring daily cleaning but the point at issue is that the organization of the program requires that all of them be recognized and that it be determined how long the cleaning operation will take. The respective tasks must be scheduled among the number of people available for cleaning.

After the daily tasks, semi-weekly and weekly cleaning operations must be planned. These may include washing down the outside of mixers and other painted equipment to maintain their appearance or, perhaps, the washing of floors in the nonproducing areas, such as the garage and product warehouse. A manifold number of such tasks can be scheduled.

Finally, biweekly, monthly and periodic cleaning tasks can be planned. These will include such items as window washing, cleaning the outside premises, spraying insecticides and application of rodent traps, all depending upon the details of the program to be established by plant management and the sanitarian.

The main interest here, however, is to emphasize that these tasks must be scheduled, described in writing and laid down, even though they are all performed by only one or two people, otherwise they will be forgotten. It is lack of planning and scheduling that is largely responsible for failure of bakeries to maintain an adequate cleaning program. The second point of failure is that not enough help is supplied for the individual tasks. This help may not always mean a large number of porters or janitors. Recently some work was done in a bakery which employed eleven janitors with no supervisor. As one would expect, the janitors loafed all day long. When they did a job they did it haphazardly and no single cleaning job ever started in the plant was properly completed. The cure for this situation was the firing of two janitors and the hiring of a full-time supervisor at somewhat higher pay than that of one janitor. As a result of this action, far more work was done by nine janitors and one supervisor, who did no actual cleaning work himself, than was even dreamed of being accomplished by the original eleven janitors. Supervision goes a long way, with proper planning, to make an efficient operation.

There are other aspects to planning the cleaning program which are important. Adequate equipment must be obtained: there must be enough mops, brooms, buckets, and the like. There must be some sort of station provided where those doing the cleaning can have access to water, both hot and cold. An industrial vacuum cleaner, with proper tools, must be provided so that dust and accretions can be removed regularly with a minimum of dirt spreading throughout the plant.

This means that if an air hose is used it must be used in such a manner that it does not blow debris to other parts of the plant where it cannot be cleaned up. This statement brings to mind a very common situation: There are two or three pieces of bakery equipment which are used to mould and pan bread doughs which simply cannot be cleaned of the accretions of dusting flour that sift through to the interior. Unfortunately the manufacturer of the equipment has shielded them too well, placing too many ledges in the equipment on which dust can settle, making cleaning almost impossible. The only method of cleaning that is in any way effective is to blow out the entire interior with a strong air hose daily. The net result is that this flour is blown all over the bakery. Probably under such circumstances, in order to use the air hose properly, it is best to wheel such pieces of equipment out of the production areas. Unfortu-

nately this is not always possible for moulder panners are frequently tied right into the production line. Care must then be taken to shield the area by setting up screens or cloths, or doing something to catch the dust before it can be blown too far. This is usually not too effective an operation since it is almost impossible to catch such dust. This situation is again—as with the flour-handling equipment—a cogent argument for the purchase of only that equipment which is cleanable.

This brings to mind the fact that, at the present time, there is a strong movement in the baking industry and in the baking equipment manufacturing industry to develop designs for bakery equipment that can be cleaned. There is an organization entitled the Baking Industry Sanitation Standards Committee, with headquarters in New York, which is contemplating the issuance of standards for the design of equipment that will be cleanable. Most bakery equipment manufacturers are cooperating thoroughly with this Committee and it is anticipated that by the end of the next ten years all equipment being offered to bakers will be of thoroughly-cleanable sanitary design. In the meanwhile every baker should, in his own interest, insist, when purchasing new equipment, that it conform as closely as possible to the rulings, or the contemplated rules, of this Committee. The work of the Committee is pretty well known, and, certainly, it is known to equipment manufacturers. The baker should not buy new pieces of equipment unless the manufacturer assures him that it is readily cleanable and that he is working in cooperation with this Committee, which has been set up in the interests of the baking industry.

Health departments are becoming more and more strict in their requirements that all bakery equipment be thoroughly cleaned, including small utensils. They are coming to regard a bakery as a sort of specialized restaurant supplier and are expecting to make the same requirements of bakeries that they are now making of restaurants with regard, at least, to the cleaning of equipment. Ultimately it can be anticipated that all food-product zone surfaces will be required to be washed and, perhaps, even sterilized at the close of each day's operation. While this may seem unduly strict, perhaps even foolish to some bakers, it must be remembered that such requirements have been developed gradually in other food industries and are now being complied with without difficulty. The same will probably be true of the baking industry later, perhaps in the not-too-far distant future.

Personnel Hygiene. A bakery, after all, is subject to the same sort of germ contamination as any other types of food-handling establishment. Bakers, in the past, have always thought they were more or less immune to food-handling requirements of health departments. The rea-

son they have felt so is because of a belief that the baking temperature to which practically all bakery products are subjected is so high that it will destroy any organisms that might contaminate the doughs through improper handling. This is probably true, except for types of organisms that are of no significance as disease carriers. However, there may be a few which can survive that are of significance to bakers, such as the bacteria that is the cause of the bread disease "rope." Basically, however, all of the pathogenic, or human-disease bearing germs or organisms, are killed by the baking temperature.

However, there are many practices in a bakery where products are handled after baking and cooling which can contaminate products and cause illness for the consumer. There is not sufficient time in this general chapter to go into this subject deeply. Suffice it to say merely that many instances have been found where food poisonings have occurred, not only in the case of cream-filled products but in the case of other products where individual poisoning occurred and only one or two people were made ill. There is even one instance of a typhoid epidemic resulting from bakery products handled by a typhoid carrier working in a plant.

What is the answer to this problem? The answer is to teach bakery employees the principles of food handling and to provide them with suitable facilities to enable them to keep themselves as clean as restaurant workers are required to be in a properly maintained restaurant. This means that food-handler training courses will have to be held within the bakery from time to time to teach the worker what his responsibilities are and the dangers of contamination that can occur in daily life. It must be remembered that a food handler who is scrupulously clean in his habits can contaminate his hands or clothing in his daily contact with life on the streets while coming to work. Unless he follows certain routine precautions he is capable of transmitting such contamination to the finished product without personally suffering in any way or ever realizing that he has contaminated others. The answer lies in education and every bakery should have a food-handler training program if it employs more than ten people. If it is not sufficiently large, then the few individuals working there can get training by attending general health department schools.

To support food-handler training properly it is absolutely necessary to provide adequate washing facilities. The small baker, working alone in his shop, simply has to follow the rule of washing his hands every time his job has been interrupted by any kind of activity, when handling icings, cakes, etc. Before returning to work on these products he must always wash his hands.

Where one has a number of employees, it is not enough to simply have a sign in the washroom saying that "employees must wash hands before returning to work, by Order of the Board of Health." The only safe way for maintenance of proper food handling in the plant is for the bakery to install a wash basin in the plant work area in plain view of the foreman or forelady, who has charge of the workers involved. It is no disgrace to be required to wash one's hands: the disgrace is in not doing so. Supervision in this regard is necessary, however: Human nature being what it is!

In closing this section it must again be emphasized that one cannot expect workers to be clean in their work unless one provides proper facilities for them to maintain themselves properly in their washrooms. The only way to encourage people to live in a sanitary manner and to work in a sanitary manner is to provide them with the best possible facilities. This does not mean that the facilities have to be fancy but they do have to be adequate. They must contain hot and cold running water, and they must be kept clean, even if it requires the employment of a special worker for that purpose. Soap and towels must be provided and lockers must be available to enable employees to keep their clothes hung properly and safely.

Pest Control. The problems of pest control have been left to the last purposely in order not to over-emphasize them; however, they are very important. It has been said that 80 per cent of bakery sanitation involves housekeeping, personnel practices, and hygiene. This is probably true for these are the basic factors in preventive sanitation and 80 per cent of the sanitation problem is, possibly, preventive sanitation.

However, despite this fact, there are always going to be casual invaders in the plant in the form of rodents and structural- and ingredient-infesting insects. A program must be set up, therefore, to take care of these before they start to breed.

Up until very recent years, bakers were pretty well convinced that the only device they had for taking care of insect infestation was spraying. Generally, bakery owners and managers were approached by two types of commercial representatives: those of the so-called pest control operator and those of the salesmen representing insecticide manufacturers. The latter argued against using the services of the former in order to convince the baker that he should buy insecticides and have his own employees apply them liberally. The pest control operator endeavored to get a standard contract for keeping infestation fairly low, but not necessarily eliminating it, so that he would have a permanent job. Both practices resulted in the continuation of insanitary plants.

Recent efforts for the establishment of sound sanitation programs by bakeries throughout the country have demonstrated that there is a place for the pest control operator in bakeries and there is a place for insecticides. However, this place must be understood by management and these valuable services must be used properly, in order to maintain sanitation and not simply to "throw money down the drain."

Let us discuss briefly what the program should be according to modern-day bakery experience and then we can determine how the baker can effectively utilize outside services if he so desires.

For rodent control, we have already seen how the problem is basically that of mice. There are very few poisons which are suitable for mice so the best method of control, once the mouse population has been reduced to a very small level, is the use of a routine trapping program. Granted, if a bakery is already rather heavily infested with mice it will be necessary to use poison bait to reduce this infestation. For mice, there is probably no other bait suitable for use in a bakery than "Warfarin," which is a new poison and, if used properly, relatively safe within the plant. It is believed that this substance should only be used by trained pest control operators, for its use in a bakery requires a good deal of time, care in placing bait and care in watching it. Some fairly large bakeries like to train one of their employees in this operation. In such case they are actually running their own pest control service. Certainly, however, "Warfarin" should not be used in a bakery if it is to be used without understanding on the part of the person applying it. A small baker should not be deceived by over-zealous salesmen of re-packaged "Warfarin" into believing he can apply this poison safely himself. This product is sold under many trade names by local re-packagers in every community in the country. It usually consists of a mixture of corn meal and a very small percentage of poison, which is to be placed in bait cups or stations. It operates when it is nibbled over a period of three to ten days and the mouse dies later, after such feeding. The mouse literally bleeds to death internally. Unfortunately mice tend to go off into obscure places to die and there may be some difficulty from unpleasant odors as a result of its use.

It is the writer's conviction that a baker would be saved a great deal of real trouble if he would go to some pains to eliminate the harborages, or nesting places of the mice, *before* using "Warfarin," for he is certainly going to have to do so *afterwards* in order to pick up the bodies of the dead mice resulting from use of the poison.

Other poisons formerly used in bakeries are not suitable. They have been ruled against by health departments and regulatory agencies repeatedly. By this we refer to such poisons as arsenic, strychnine, thal-

lium and Compound 1080. "Warfarin" is the only safe poison bait now recommended by health authorities for use in bakeries.

For insects, one must consider the type of insect for which control is desired. Structural insects can be controlled most effectively by applying a residual deposit of some suitable insecticide. In the past, 5% DDT, and 2% chlordane have been recommended, but recently there has been considerable experimental work and field observation which has disclosed that this application may be dangerous and it is now not recommended that they be used generally in the interior of bakeries. If there is a marked infestation in the plant, either relatively less harmful products should be used, or very extreme care should be exercised to insure that the use of DDT or chlordane is not carried out in a manner that might contaminate the finished product.

At this point the question will undoubtedly be asked: "What are the relatively less harmful insecticides?" At the present time there are mixtures of pyrethrins, rotenone derivatives and a substance known as piperonyl butoxide which are available in various combinations on the market and recommended for residual use by their manufacturers.

The preparations recommended as residuals must not be confused with those recommended as contact or space sprays. The same substances are contained in each type of insecticide but in different proportions. A residual insecticide is one designed to leave a very thin layer of the insecticidal poison on a sprayed surface which will later poison insects walking in it. A contact insecticide is one designed to kill those insects with which it comes in contact at the particular time of spraying and then only. Mixtures of pyrethrin and piperonyl butoxide, known as pyrenone, are recommended in different concentrations for both uses. There is no question that, as a contact insecticide, such mixtures have been shown to be very effective but there is some question at the present time as to whether or not these combinations form effective residuals. The same is true of mixtures of pyrethrin and rotenone derivatives. Although not generally as well known as the pyrethrin-piperonyl butoxide mixtures (pyrenones), rotenone mixtures are known on the market and have been shown to have excellent contact and some residual properties. This latter qualification is made because, so far, residuals composed of these products have been shown to be effective but they may not retain their effect anywhere as long as chlordane and DDT do. Other substances are also being offered from time to time, such as methoxychlor and lindane. There is evidence that these latter have some residual effect in certain concentrations, although this fact has not been demonstrated conclusively under the conditions in which they might be used in bakeries.

These three combinations have been fairly well exonerated of being composed of any toxic characteristics by Government testing laboratories. They are not to be confused with DDT and chlordane, which are at the present being subjected to a great deal of criticism.

It must be borne in mind, however, when residual deposits of any insecticides are used that all insecticidal substances are poisonous and have no place in bakery ingredients as an ingredient or adulterant. Extreme care must be taken in laying down such deposits so that they will not contaminate ingredients or food-product zone surfaces. At the end of this chapter there is included a résumé of "Directions for Applying Residual Deposits."

There are some flying insects common in the bakery. These can be killed by periodic space spraying; however, extensive space spraying of contact sprays in the bakery can prove very expensive. It is recommended that space sprayers of a portable type be used which deliver a very fine particle spray or fog. Insecticides to be used for this purpose consist primarily of the same types of mixtures described in the previous paragraph as being considered relatively safe. It must be remembered that when space sprays are used all food-product zones must be covered lest the finished product become contaminated later as a result. Pyrethrin, piperonyl butoxide or pyrenone mixtures are permissible here; pyrethrin-rotenone derivative mixtures are permissible too; however, no chlorinated hydrocarbons, including DDT, chlordane, methoxychlor or lindane should be used for space spraying in the bakery.

More recently, vaporization insecticide applicators have been developed. These are small devices which create a vapor of lindane, but in the past have used DDT. Perhaps in years to come they will use some other substance. Government tests have shown that these devices generate a very low concentration of insecticide vapor in the atmosphere, probably less than that resulting from heavy spraying of residual deposits. However, their effectiveness depends on the frequency of air changes in the room in which they operate. It is doubtful that such would be suitable in a bakery, except in rooms kept relatively quiet. For rooms with not more than eight air changes per hour they have been shown to be quite effective in controlling flying insects such as flies and moths.

The writer has often been asked whether or not a bakery should use outside pest control operators or develop its own pest-control methods. The answer to this question depends entirely upon the individual bakery. If there is personnel in the plant with adequate time to develop themselves as pest control workers, there is no reason why they should not do so. Many bakeries do and have a very effective program of their own.

On the other hand, however, there are many bakeries that do not feel that they wish to take on pest-control operation as a side line, and they bring in outside operators who, working in cooperation with the plant manager, have helped develop a very effective bakery program of control. However, there is a sanitation problem even when this is done. This is often due to the fact that the pest control operator does a great deal of work in establishments other than food-producing plants. Unless their operations are properly supervised by the bakery manager, the operators from pest control companies tend to follow the same procedures they use in ordinary warehouses. These cannot be permitted in a bakery in many instances, so the bakery suffers. The baker must remember that it is he who is responsible for his own sanitation program and he cannot "wish it off" on the shoulders of a pest control operator. The pest control operator can only work as the baker's agent and if anything should go wrong and if any mistake results in poisoning, for example, it will be the baker who will have to assume the blame, not the pest control operator. In answer to this accusation, many of the pest-control industry point out that they all carry heavy insurance. This is granted, but it is not the actual financial loss that hurts the baker; rather, it is the loss of prestige he suffers when something goes wrong. It is the baker who is responsible under health laws, not the pest control operator.

It is impossible to write a whole text on bakery sanitation in the small space available. However, it is believed that the following summary may serve as a good reminder of the essential points of a bakery sanitation program and that the two tables of directions, one for setting up a mouse-trapping program and the other for establishing rules for proper application of sprays, also included herein, will help the baker in developing these programs.

Any baker really interested in developing and bettering his sanitation program should seek expert advice in developing the details. In the long-run it will pay off.

RULES FOR METHODS OF APPLICATION OF RESIDUAL SPRAYS OF DDT AND CHLORDANE

(1) Use only 5% solution of DDT or 2% solution of chlordane dissolved in deobase-type solvent. Such a spray already prepared can be obtained from commercial sources, but care should be taken to insure that the solvent used is colorless, odorless, noncorrosive and nonstaining.

(2) The spray should be applied by painting the surface to be covered with a spray coming from a flat spray nozzle installed upon a pressure hand spray tank capable of operating between 32 and 50 pounds air pressure. Such a tank is manufactured commercially by several sources. It comes equipped with two types of valves, a brass trigger valve which tends to drip when closed off and a squeeze type valve locked in the hose itself which does not drip. The latter one is recommended.

Such sprayers come equipped with several types of nozzles. A solid stream nozzle is used for directing residual spray into cracks and crevices under high pressure. The flat spray nozzle is used for painting spray on wall surfaces. A misting nozzle can be obtained for use in spraying with contact sprays on occasion.

(3) The operator first pumps up the tank to a pressure of 50 pounds. The pressure must be reapplied when it falls to 32 pounds. The spray must be applied with an even up-and-down motion so that a film of liquid covers the desired surface to such a degree that the surface, when freshly covered, glistens but does not run. The wand or nozzle should be held approximately 18 inches from the surface being sprayed. Experience will dictate the exact distance. The usual method is to apply the spray to a height of about five feet on walls and approximately one-half to three feet out on the floor. The rate of application for the spray is at the rate of one gallon per thousand square feet covered. A rough check should be made to determine the number of square feet covered with each application so that a correction may be made if the spray is being applied too heavily or too lightly.

(4) During the spraying operation all windows must be left open to provide adequate ventilation. Unless this is done the operator may be annoyed by the vapor from the oil or the auxiliary solvent in the spray material. It is perfectly safe when used under good ventilation, however. The solvent for the spray is inflammable and for that reason should not be used near open fires. Thus, the spraying had best be done on Saturday when the ovens and the like are turned off.

(5) During the spraying operation the operator may wear rubber gloves to protect his hands from the spray. If he does not wish to wear gloves, he should carry a clean dry rag so that he can immediately wipe off any spray solution that may get on his hands. This is necessary because some persons are allergic to the oil solvents. In any case, the operator should wash his hands thoroughly at the completion of the spraying operation. Only oil base solvents should be used, for all others incorporate water as part of the solvent. The water solution is a conductor of electricity and is therefore dangerous when used around electrical equipment. The oil base spray is a nonconductor of electricity and can be safely used around motors, switch boxes and other electrical equipment. In fact, the switch boxes should be blown out immediately prior to application to eliminate dust residues therein, and an application of spray may then be applied to their interior.

(6) The operator must be sure that he applies the spray so that it does not come into contact with any of the raw ingredients or the product zones of the equipment.

(7) Before undertaking to apply the spray, the operator must determine exactly where he wants to apply it. In the storage rooms, this should include the walls up to five feet from the floor, the floors to within a foot and a half of the walls, the bottoms of skids and cracks of skids, the interior of any switch boxes, surfaces of beams or overhead pipes or any spaces where flour dust tends to accumulate, the interior of lockers, the interior of electric motors, screens and around windows and such places that make excellent harborage that can not be removed. These places are the ones that should be sprayed with DDT in 5% deobase-type solvent.

(8) Chlordane in 2% solution deobase-type solvent should be applied to all damp areas and to drains. Indeed, chlordane should be used primarily only for the control of cockroaches. If any nesting places for these are found they should be saturated with chlordane spray solution.

(9) The operator doing the spraying in all cases must make a record of the surfaces covered in order that a complete coverage can be achieved and a final record exists of what has and has not been sprayed, and the time it was sprayed.

MOUSE TRAPPING METHODS

Facts to Know: Difficulties from mouse invasion of the plant may be expected during the fall months when cold weather drives them inside from vacant lots and other outside habitats. House mice are not particularly wide-ranging so that a family or colony may exist in one corner of a large room. They hug the walls or otherwise confine their activities to the close proximity of stacked foodstuffs and equipment that affords safety in quick retreat. Keep storage active! Poor housekeeping that allows packaging and little-used equipment to accumulate in undisturbed sections of the plant favors a mouse infestation.

Traps: The success of the operation depends more on the ingenuity of the operator and the persistence in setting and tending the traps than in the traps themselves. The simpler the trap the greater its practical value for taking mice. The common, wooden-base snap trap that has been used for many years is still the best tool. Such traps should be baited but the baits need not be attached or confined to the trigger. It is not necessary to handle the traps with gloves, or to smoke or wash them to remove odors.

Baits: A cereal base bait should be prepared according to one of the following formulas:

Dry oatmeal or yellow cornmeal	95%
Melted bacon fat	5%

Dry bread or cake crumbs	95%
Honey or syrup	5%

Allow bait to dry and then screen to small-size crumb. Use as needed.

Placement: Distribute traps on floor and shelves, concentrating the numbers where tracks in the flour dust or droppings on floor and sacks indicate the presence of mice. They should be placed perpendicular to the wall so that the trigger is in the runway while the spring and metal parts are out of the way. Bait should be sprinkled over the fore part of the trap so that some fragments fall on the floor at the side, which will serve as "prebait."

It is a good practice to keep traps set in out-of-the-way places like under platforms and in basement and attic rooms where they will take invading mice before they gain a foothold in the plant. These traps should be tended once a week by some designated employee.

STANDARDIZED BAKERY SANITATION PROGRAM

A. *Management and Participation*
   1. *Manager*
      a. Must be thoroughly familiar with basic principles of sanitation.
      b. Must participate personally as much as time will permit.
      c. Must take responsibility for providing adequate equipment and budget.
   2. *Sanitarian—Full Time or Part Time*
      a. Responsible directly to manager.

b. Not the same as head janitor or sanitation foreman.
c. Full-time sanitarian must be technically trained and drawn from outside of plant.
d. Part-time sanitarian from supervisory personnel only. Must be relieved of part of other duties and given sufficient time to properly carry out sanitation duties.
e. Must develop spirit of cooperation with other departments.
f. Must plan and supervise application of all schedules:
   1. Inspection
   2. Cleaning
   3. Spraying
   4. Fumigating
   5. Rodent Control
g. Must keep technically informed.
h. Must plan and administer educational program.

B. *Inspection Program*

1. Sanitation Committee composed, in order of importance, of:
   Sanitarian—Secretary
   Manager
   Production Superintendent
   Engineer
   Shipping Superintendent or others, as conditions indicate
   Sales Manager

   This committee is responsible for the plant's program, for planning, and for better cooperation. It must hold weekly meetings of no longer than thirty minutes. It must keep written records.
2. Plant Inspection

   Entire plant should be covered at least once a month by the frequent inspection of small areas or equipment selected by committee.
3. Outside Appraisal Inspection

   Should have regular outside survey by, or equivalent to, American Institute of Baking inspection.

C. *Ingredient Control*

1. Inspect flour at time of receipt.
2. Examine flour sifter tailings daily. Maintain a record of number of insects found.
3. Check exterior of ingredient packages for insect infestation or rodent damage.
4. Again check ingredient package contents at time of use for visible evidence of insects or rodents.

D. *Cleaning Responsibilities*
  1. All cleaning operations should be scheduled by area or by job and not by individuals.
  2. Porters should be rotated whenever possible.
  3. Mark priority jobs so if one porter is absent the least important work on two schedules can be skipped.
  4. Make provisions for vacations.
  5. Follow frequency chart.

E. *Pest Control*
  1. Rodent Control
     a. Manager must know: what, where and when poisons are used.
     b. Only poisons safe for use:
        Red Squill—rats only
        ANTU—Norway rats only
        Warfarin—all rodents.
     c. Recommended measures:
        For mice: traps only. Follow "Mouse Trapping Rules."
        For rats: ANTU or Red Squill, traps.
  2. Insect Control
     a. Residual deposits for casual invaders
        DDT safer than chlordane but both dangerous for inside use except under very strict control. Less poisonous residuals are now available but must be used more frequently.
     b. Contact sprays for flying insects
        Only pyrethrum, piperonyl butoxide and rotenone derivatives safe for use as contact spray chief ingredients.

        DDT or chlordane are not permitted.

APPENDIX

PROPOSED BREAD STANDARDS

(Complete text of findings of fact and proposed bread standards as published in the *Federal Register,* August 8, 1950)

[21 CFR, PART 17]
[DOCKET NO. FDC-31 (b)]

BAKERY PRODUCTS; DEFINITIONS AND STANDARDS OF IDENTITY

NOTICE OF PROPOSED RULE MAKING

In the matter of definitions and standards of identity for the following foods: bread, white bread, and rolls, white rolls, or buns, white buns; enriched bread and enriched rolls or enriched buns; milk bread, and milk rolls or milk buns; raisin bread and raisin rolls or raisin buns; whole wheat bread, graham bread, entire wheat bread, and whole wheat rolls, graham rolls, entire wheat rolls, or whole wheat buns, graham buns, entire wheat buns; breads and rolls or buns made with combinations of flour, whole wheat flour, cracked wheat, and crushed wheat; and unsalted breads and rolls or buns:

It is proposed that, by virtue of the authority vested in the Federal Security Administrator by the provisions of the Federal Food, Drug, and Cosmetic Act (secs. 401, 701, 52 Stat. 1046, 1055; 21 U. S. C. 341, 371) and upon the basis of substantial evidence received at the public hearing held pursuant to the notice published in the FEDERAL REGISTER on October 14, 1948 (13 F. R. 6023), and upon consideration of proposed findings of fact filed by interested parties, which are adopted in part and rejected in part as is apparent from the detailed findings made below, the following order be made:

FINDINGS OF FACT—BREAD

Findings of fact. 1. The food commonly and usually known as "bread" or "white bread" and that commonly and usually known as "rolls," "white rolls," "buns," or "white buns" are prepared by baking a kneaded yeast-leavened dough made by moistening flour with water (or with certain other liquid ingredients hereinafter specified, alone or in combination with water) with the addition of salt, and usually with the addition of certain other ingredients as hereafter set forth. Bread and rolls are sometimes prepared from bromated flour or phosphated flour or both, with or without admixture with plain flour.

ROLLS AND BUNS

2. Rolls, sometimes known as buns, differ from bread in the size of the units baked, and usually in their shape. A reasonable and satisfactory differentiation is that a

loaf of bread weighs, after cooling, one-half pound or more, whereas a roll, after cooling, weighs less than one-half pound.

SALT-FREE BREAD

3. White bread and, at times, other types of bread are sometimes made without added salt, for special dietary use. These breads are often referred to as salt-free breads. A more accurate modifying designation is "unsalted." They serve a useful purpose when sold to persons who know their characteristics and use them as a special type of bread.

MOISTURE LIMITATION

4. All bread and rolls contain moisture. An excessive moisture content tends to defraud consumers. A reasonable maximum limitation upon the moisture, which is somewhat in excess of the usual content, is 38 percent by weight, the solids being not less than 62 percent by weight. A satisfactory and reliable method for determining the total solids contained in bread and rolls is the method prescribed in "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists," Sixth Edition, 1945, page 260, section 20.84 (a), "Total Solids in an Entire Loaf of Bread—Official," except that if the baked unit weighs 1 pound or more, one entire unit is used for the determination, and if the baked unit weighs less than 1 pound such number of entire units as weigh 1 pound or more are used for the determination.

LECITHIN—GLYCERIDES

5. Shortening is commonly, but not always, added to bread dough. Any food fat or food oil, including butter, oleomargarine and cream or any mixture of two or more of these, is suitable for this purpose. For accentuating the shortening action of fats and oils, lecithins derived from corn oil or soybean oil (which with their associated phosphatides are both commercially known as lecithin) and mono- and diglycerides of fat-forming fatty acids are sometimes used, and are suitable for such use. Lecithin was proposed as an ingredient of the dough apart from its use as an ingredient of shortening. There was no substantial evidence, however, that it serves any useful purpose other than as an ingredient of shortening. In 1942, mono- and diglycerides in limited amounts, usually not exceeding 5 percent, were used in many types of shortening. Since 1942, experience has shown that even larger proportions of mono- and diglycerides in the shortening still further increase the shortening effect. Although detailed data as to the physical properties of bread prepared with varying amounts of shortenings containing varying amounts of mono- and diglycerides are not shown in the record, it is evident that when the mono- and diglyceride content of the shortening does not exceed 25 percent no properties are imparted by it to bread other than those commonly associated with the use of shortening.

ACETYLATED TARTARIC ACID

6. In addition to mono- and diglycerides of fat-forming fatty acids, corresponding compounds have recently been developed in which acetylated tartaric acid has been substituted for fat-forming fatty acids. Compounds of this kind have been used to

some extent in bread dough. Their effect on the bread is very similar to that resulting from the use of similar quantities of mono- and diglycerides of fat-forming fatty acids. Prior to the use of mono- and diglycerides of acetylated tartaric acid there had been no known employment of acetylated tartaric acid in preparing a food ingredient. Limited studies have been made of the physiological effects following the ingestion of acetylated tartaric acid. It appears to have little, if any, food value. Proponents of the use of the mono- and diglycerides of acetylated tartaric acid assumed, but did not present evidence to prove, that the pharmacological properties of acetylated tartaric acid are the same as those of tartaric acid. The evidence showed that when mono- and digyclerides of acetylated tartaric acid were fed to animals in amounts somewhat exceeding those that would normally be present in bread there was no observable injury. Further experiments showed, however, that the acetylated tartaric acid was not broken down into acetic acid and tartaric acid in the bodies of the animals for a considerable time. Whether for this reason any adverse effect on humans might result was not definitely known. Although no injury was noted in the limited experiments carried out, the introduction into the human body of a substance such as acetylated tartaric acid, whose properties have not been thoroughly studied, cannot be justified by necessity for its use or by any advantages that the mono- and diglycerides of this acid may have over those of mono- and diglycerides of the fatty acids. The evidence does not justify a finding that the recognition of the mono- and diglycerides of acetylated tartaric acid as an optional ingredient of bread, rolls, and buns would promote honesty and fair dealing in the interest of consumers.

SHORTENING

7. The quantity of shortening used in bread dough varies widely. Some breads contain no shortening. The evidence affords no basis for concluding that the fixing of any maximum or minimum limits for shortening would serve consumer interest. The usual quantities of shortening are between 2 and 6 parts by weight for each 100 parts by weight of flour used, and seldom exceed 12 parts except in the cases of "sweet goods" and "specialty goods," products so distinctively different from bread and rolls as to be unlikely to be confused with bread or rolls by consumers. Such products usually contain from 12 to 30 parts of shortening. The possible effect of the use of products referred to as emulsifiers on the quantity of shortening used in bread and rolls is discussed in finding 39.

MILK AND MILK PRODUCTS

8. Milk and various milk products are widely used in making bread and rolls and serve to improve their nutritive value and modify certain physical characteristics. In addition to fluid milk there have been used for these purposes, singly or in combination, concentrated milk, evaporated milk, sweetened condensed milk, dried milk, skim milk, concentrated skim milk, evaporated skim milk, sweetened condensed skim milk, sweetened condensed partly skim milk, and nonfat dry milk solids.

9. In order to set bread made with any of the ingredients specified in finding 8 apart from milk bread, it is reasonable that such ingredients, together with any butter and cream used in bread, be so limited in quantity or composition as not to meet the requirements prescribed in findings 54 to 57, inclusive, for the quantity and composition of such ingredients in milk bread.

10. Nonfat dry milk solids are widely used in the baking industry as an ingredient of bread and rolls. Occasionally bakers receive shipments of nonfat dry milk solids which have unsatisfactory baking qualities. The causes of poor baking qualities in these occasional lots of nonfat dry milk solids are not well understood. A proposal was made to provide, for use as an optional ingredient in bread or rolls, of nonfat dry milk solids that had been treated with calcium and magnesium oxides and to which soy flour was added. The mineral salts were said to neutralize any excess acidity of the product and improve its baking qualities. Testimony was incomplete relative to the type of nonfat dry milk solids used in preparing this combination, its acidity, and whether the properties of the finished mixture depended upon neutralization of the acidity of the nonfat dry milk solids. The evidence did not show that such modified nonfat dry milk solids had any better baking qualities by reason of the addition of calcium and magnesium oxide and soy flour. Calcium and magnesium oxides serve no useful purpose in bread or rolls. The use of soy flour as an ingredient of bread is described in other findings.

DRIED CHEESE WHEY

11. During and shortly after the Second World War, nonfat dry milk solids were in short supply in the baking industry, and manufacturers of dairy products developed a dried cheese whey as a substitute for nonfat dry milk solids in bread and rolls. Dried cheese whey contains more lactose and less protein than nonfat dry milk solids. When prepared from proper raw materials cheese whey is suitable for human food. Although the properties imparted to bread by cheese whey are not identical with those imparted by nonfat dry milk solids, cheese whey performs certain desirable functions in bread. However, when cheese whey is used in place of nonfat dry milk solids the loaf volume of bread is decreased. In order to make the action of dried cheese whey simulate that of nonfat dry milk solids on the mixing time and loaf volume of bread, some manufacturers experimented with cheese whey containing calcium sulfate, and obtained a loaf volume comparable to that obtained with similar quantities of nonfat dry milk solids. In some of their experiments the cheese whey was first treated with sulfuric acid which was later neutralized by the addition of lime, thus forming calcium sulfate. Whether the use of this process actually changed some constituents of the whey or whether the added calcium sulfate increased the size of the loaves of bread in which this type of whey was used is not clear. The evidence does not show that the use in bread and rolls of cheese whey so processed would promote honesty and fair dealing in the interest of consumers.

ALBUMIN

12. Another ingredient of milk (usually prepared from whey but sometimes from skim milk) proposed for use in bread and rolls is a mixture of proteins consisting largely of albumin. The nutritive properties of these mixed proteins are very similar to those of casein, which supplies most of the protein in nonfat dry milk solids. Although formerly the cost of separating albumin from whey has been such that it has not been used to any substantial extent as a separate ingredient in foods, such albumin is a valuable food ingredient and serves somewhat the same purpose in bread as the proteins of nonfat dry milk solids. Albumin in amounts likely to be used would cause no noticeable change in the physical characteristics of the bread or rolls. There were indications from the testimony of proponents of the recognition

of albumin as an optional ingredient of bread that its use would be accompanied by exaggerated representations, through labeling or advertising, that bread containing albumin had special nutritive properties. Although such promotion is not in the consumer interest, prohibition of the use of albumin does not appear warranted. The information required by the regulations prescribing the labeling of foods for special dietary use (21 CFR 125.1 et seq.) will aid in preventing consumer deception.

BUTTERMILK

13. Buttermilk, concentrated buttermilk, dried butter milk, sweet cream buttermilk, concentrated sweet cream buttermilk and dried sweet cream buttermilk, singly or in combination, are sometimes used in bread making, for purposes similar to those stated for the dairy ingredients specified in finding 8.

EGGS AND EGG PRODUCTS

14. Liquid eggs, frozen eggs, dried eggs, egg yolks, frozen yolks, dried yolks, egg white, frozen egg white, and dried egg white, singly or in combination with each other, are sometimes used in bread making, for the purpose of improving the nutritive value and imparting other desired characteristics.

15. As the quantity of egg solids or egg-yolk solids in the dough is increased, the characteristics imparted to the baked product by such solids become more noticeable. The evidence does not establish the point at which the quantity of such solids results in products of identities different from bread and rolls, although the evidence indicates that such point lies between 2 parts and 5 parts for each 100 parts of flour.

SWEETENING PRODUCTS

16. In making bread or rolls certain saccharine products are commonly used to furnish fermentable carbohydrates, to control the color of the crust, and to alter the taste, frequently to the extent of imparting some sweetness to the finished product. These include sugar, invert sugar (in sirup or congealed form), light-colored molasses, light-colored brown sugar, refiners' sirup, dextrose, honey, glucose sirup, corn sirup, dried corn sirup, nondiastatic malt sirup, and nondiastatic dried malt sirup. All these products, used either singly or in combination with each other, are satisfactory for the purpose stated.

BLACKSTRAP MOLASSES, ETC.

17. Blackstrap molasses and dark-colored brown sugar, by reason of their color and other properties, are unsuitable for use in bread or rolls. Concentrated water extract of raisins and concentrated water extract of prunes have been proposed as saccharine ingredients in bread or rolls, but are not shown to be suitable for this purpose, especially because of their color and taste.

SACCHARINE SUBSTANCES

18. If carbohydrates are desired only for yeast fermentation, the quantity of saccharine substances added generally does not exceed 3 parts by weight, on a dry basis, for each 100 parts by weight of flour. When the baker wishes to produce some minor change in taste or in the appearance of the crumb or crust, increased quanti-

ties are used. Such baked products are considered by consumers as ordinary white bread or rolls unless they are definitely sweet or have acquired other definite characteristics from such ingredients.

LIMIT OF SWEETNESS

19. It is impracticable to prescribe a maximum limit for saccharine ingredients generally in white bread or rolls because of the wide differences in the respective sweetness and other characteristics of such ingredients and because even where sugar alone is used the evidence is not definite as to the quantity above which an article ceases to be ordinary bread and becomes sweet goods, although 16 parts by weight of sugar to each 100 parts by weight of flour appears to be near the average for sweet goods.

INACTIVE DRY YEAST

20. Inactive dry yeast is occasionally used to impart a flavor, sometimes referred to as a "homemade flavor," to bread and rolls. If added in excess of 2 parts per 100 parts by weight of flour used, inactive dry yeast adversely affects the color of the crumb and crust. Inactive yeast of the Saccharomyces cerevisiae type, which is the type of yeast used for leavening, is suitable for the above purpose in quantities up to 2 parts per 100 parts by weight of flour used. Inactive yeast of the Torulopsis utilis variety was also proposed as an optional ingredient of bread and rolls. This type of inactive dry yeast is used to some extent in the United States as an ingredient of animal feeds and was used in Europe as a dietary supplement for humans during the wartime food shortages. Inactive dry yeast of the Torulopsis utilis variety has not been used in bread or rolls in the United States except experimentally. The evidence does not show that there is any demand on the part of bakers for inactive yeast of this variety or that under the conditions under which it is now produced it is suitable for use as an ingredient of bread and rolls.

MALT PRODUCTS

21. Malt sirup, dried malt sirup, malted barley flour, and malted wheat flour, each of which is diastatically active, are frequently used, singly or in combination with each other, in making bread or rolls. These substances are generally used to compensate for a deficiency of natural enzymes in the flour used, and when used for this purpose alone the quantity is limited to about 0.25 percent of the weight of the flour. In certain kinds of hearth bread, however, quantities of malt sirup or dried malt sirup as high as 4 percent, or even higher, are used to improve the crust characteristics, especially the color of crust.

ENZYMES

22. The desired action of malt flour and diastatically active malt sirups in bread dough is primarily due to their content of certain enzymes that act upon the starch of the flour during the fermentation of the dough. The action of these enzymes is rather complex and affects the baking qualities of the dough in several ways. Recently it has been found that enzymes having a somewhat similar action on the starch of flour can be obtained from media in which certain molds, particularly

Aspergillus oryzae, are grown. Purified preparations containing enzymes from Aspergillus oryzae are suitable for use in bread making.

FLOUR OTHER THAN WHEAT

23. Consumers normally expect white bread and rolls to be essentially products of wheat flour. At various times in the past, however, when there has been a scarcity of wheat flour, other similar grain products, especially corn flour, have been extensively used to replace part of the flour in making bread and rolls. Potato mash is sometimes used to develop a preliminary yeast growth and is then incorporated in the dough. So-called dusting flour, often consisting in whole or in part of farinaceous products other than wheat flour, has long been in common use to prevent the dough from sticking to the receptacles or a machinery; a considerable proportion of such dusting flour becomes incorporated in the dough. Dextrinized starch is believed by some to have the property of retaining moisture in bread after baking. The advisory standards issued by the Secretary of Agriculture for white bread, beginning with the first such standard in 1923, have all recognized the propriety of such practices to the extent of the replacement of not more than 3 percent of the wheat flour by some "other edible farinaceous substance."

CORN & RICE FLOUR, ETC.

24. Products that have been used and are suitable for one or more of the purposes stated in finding 23 are corn flour or finely ground corn meal, potato flour, rice flour, cornstarch, milo starch, potato starch, sweet potato starch, and wheat starch. Sometimes these products are wholly or in part dextrinized. Dextrinized wheat flour is also suitable for such use. In recent years soy flour has also been used in small amounts. At times one or more of such starches or flours are used in preparing pastes in which flavors are developed by the action of certain harmless souring organisms. These pastes are dried and the material used as an ingredient of bread or rolls for the purpose of slightly modifying their flavor.

25. Use in making white bread or rolls of any one or more of the products specified in finding 24, in a total quantity not greater than 3 parts by weight for each 100 parts by weight of wheat flour used, does not run counter to the normal expectation of present-day consumers.

SOY FLOUR

26. Subsequent to the hearing held in 1942, a great many bakers had experimented with the use of various quantities of soy flour in bread. Their experience shows that up to 3 parts of soy flour to 100 parts flour may be used without a substantial change in the physical characteristics of white bread. Within this limit, many bakers wish soy flour recognized as an optional ingredient, as described in finding 24. When bakers use more than this amount of soy flour they do so primarily because they wish to increase the protein content of the bread. As the soy flour content of bread is increased above 3 parts per 100 parts of flour, the taste and color of the bread are progressively changed. Special breads known as wheat-and-soya breads have been sold containing varying proportions of soy flour. No interest was manifested by the persons desiring to use soy flour in bread in excess of 3 parts per 100 parts of flour in the adoption of a definition and standard of identity for wheat-and-soy bread.

PEANUT AND COTTONSEED FLOUR

27. Products referred to as peanut flour and cottonseed flour were proposed for use as optional ingredients in bread and rolls, in quantities up to 3 parts per 100 parts of flour. These products were said to serve the same purposes as the products described in finding 24 and also to contribute substantial nutritive values. Cottonseed flour was not proposed as an ingredient in white bread and rolls. The evidence does not show that these products have been used to any material extent in making bread or rolls or that they are suitable for such use.

OAT PRODUCTS

28. Rolled oats, ground oatmeal, and oat flour were proposed as optional ingredients for inclusion with the products specified in finding 24, on the ground that such oat products are economical and nutritious foods and furnish a distinctive and desirable flavor. The evidence does not establish that any of these products have been used in making white bread or rolls, or their suitability for such use.

SPECIAL OAT BREAD, ETC.

29. The evidence does not establish that the use of the products listed in findings 27 and 28 results in any significant improvement in nutritive properties when the quantities used are not more than 3 parts to each 100 parts of flour; it does indicate that the inclusion of such products in white bread would run counter to the normal expectation of consumers. The evidence furnishes no basis for a determination of what quantities of such products should be used with flour to produce breads of different identities recognizable as such by consumers.

WHEAT GERM

30. Wheat germ processed in various ways to modify its enzymatic activity and to prevent rancidity has been used as an ingredient in some white bread. The processing may consist of heating it, treating it with potassium bromate, removing part of the wheat germ oil, and possibly of treating it in other ways suggested but not described in the record. Such processed wheat germ was proposed as an optional ingredient for the purpose of imparting flavor and improving some of the physical characteristics of white bread. No proposal was advanced for recognition of the use of unprocessed wheat germ such as that naturally present in small amounts in flour. The testimony regarding benefits from the use of small amounts of processed wheat germ in white bread (1½ to 2 parts by weight of processed wheat germ per 100 parts by weight of flour) is not convincing. On the other hand, there was evidence establishing that the use of processed wheat germ in white bread has led to labeling and advertising claims, based on its vitamin and mineral content, that might confuse consumers with respect to identity and relative nutritive properties of bread and enriched bread.

DEHULLED SOYBEANS

31. Ground dehulled soybeans, with or without heat treatment and with or without removal of oil, but which retain their enzymatic activity, exert a bleaching action upon flour in bread dough. The use of such products in dough permits the pro-

duction of light-colored bread or rolls from unbleached or slightly bleached flour. Substantial quantities of ground dehulled soybeans have been used for this purpose for many years. For this bleaching effect it is not necessary to use more than 0.5 part by weight of such a product to each 100 parts by weight of flour used.

MINERAL SALTS

32. In making bread and rolls it has become a widespread practice among bakers to add to the dough small quantities of certain mineral salts, commonly known by such designations as yeast foods, dough conditioners, and bread improvers. Calcium and ammonium salts are used to stimulate the growth of yeast during fermentation. Other salts, which act as oxidizing agents are used to affect the process of fermentation, although the evidence establishes no satisfactory scientific explanation of the mechanism of their action. The evidence indicates that the addition of so-called dough conditioners tends to lessen the variability in the qualities of the dough resulting from differences in characteristics of the flour used, differences in water supply, and other factors, and thereby to facilitate the handling of the dough in mechanized bakeries.

CALCIUM AND AMMONIUM SALTS

33. The calcium salts used for the purpose described in finding 32 are monocalcium phosphate, dicalcium phosphate, calcium sulfate, and calcium lactate. Calcium carbonate has a limited use in a so-called double-strength dough conditioner. Ammonium salts used for this purpose are monobasic and dibasic ammonium phosphates, ammonium sulfate, ammonium chloride, ammonium carbonate, and ammonium lactate. Ammonium carbonate and ammonium lactate, however are no longer of commercial importance. It is not necessary to use any of these salts or any combination of them in a quantity greater than 0.25 part by weight for each 100 parts by weight of flour used.

OXIDIZING AGENTS

34. The over-all effect of the use of varying kinds and quantities of oxidizing agents in bread dough is usually judged by the change in the size of the loaf in comparison with similar loaves baked from dough to which no oxidizing agents are added. The use of too large a quantity of an oxidizing agent is likely to cause a decrease in loaf volume.

There was no evidence that potassium bromate, potassium iodate, and calcium peroxide in the amounts commonly used leave residues or cause the formation of oxidation products which might make the bread injurious to health. Due to uncertainty as to the end-products resulting from the action of oxidizing agents on the ingredients of bread and to the fact that they leave small residues (potassium bromate leaves a residue of potassium bromide, and potassium iodate a residue of potassium iodide) which serve no useful purpose in bread, it is desirable that the amounts of such substances used be restricted to a minimum. It is not necessary to use any of these oxidizing agents or any combination of them, including the potassium bromate contained in any bromated flour used, in a quantity greater than 0.0075 part by weight for each 100 parts by weight of flour used.

In 1942 sodium chlorite was proposed as an optional oxidizing agent. It was shown by rather limited experimental use to be suitable for use in bread. Al-

though accorded tentative recognition in the proposed order published in 1943, no evidence was presented to show that it has been used commercially or experimentally since that time or that there is any desire on the part of the baking industry to use this product.

Ammonium persulfate and potassium persulfate have been used to a limited extent as ingredients of so-called dough conditioners in the United States. These salts have at times been added to flour in countries other than the United States, for the purpose of affecting the properties of dough and bread made therefrom. There was evidence indicating that dough prepared from flour containing persulfates has been the cause of the sensitization of some of the persons handling it and that frequent handling of such dough caused allergic manifestations (dermatitis). The evidence does not justify the finding that ammonium persulfate and potassium persulfate are suitable ingredients for use in bread or that their use will promote honesty and fair dealing in the interest of consumers.

GRAIN INFUSION

35. A product described as grain infusion was proposed for use as a yeast food and bread improver. It is a mixture of concentrated corn steepwater (neutralized with calcium carbonate) and dextrinized cornstarch, with added ammonium chloride, salt and potassium bromate. The concentrated steepwater, a byproduct of the starch industry now generally used for cattle feed, is made by concentrating the liquid obtained by steeping corn in water containing 0.15 percent of sulfur dioxide. The so-called grain infusion as sold to the baker contains approximately 0.002 percent of sulfur dioxide, which is oxidized during fermentation and baking. The evidence does not establish that this so-called grain infusion is suitable for use in bread or that it improves the quality of bread otherwise than through the action of the calcium and ammonium salts and the potassium bromate contained in it.

AMINO ACIDS

36. Amino acids, especially cystine, were proposed as a substitute for the oxidizing agents in bread or rolls. The evidence does not establish the suitability of such acids for this purpose.

SPICE PRODUCTS

37. Spice is sometimes added to bread or rolls, usually on the surface, but occasionally by incorporation in the dough. Spice oil and spice extracts have been used to a slight extent. Such additions materially affect the flavor of the bread or rolls. Consumers do not ordinarily expect such additions unless announced by appropriate label statement. Such statements which are accurate and informative are "spice added," "with added spice," or such statements in which the common or usual name of the spice is substituted for the word "spice."

STALE BREAD

38. Bread is subject to deterioration and spoilage. The most common form of deterioration is staling. Old bread or stale bread is harder than fresh bread, its taste has changed, and it is almost universally regarded as less desirable than fresh bread. The length of time for staleness to develop varies, depending on several factors; but it is the common practice of many bakers to withdraw bread from sale 2 days after baking. Some bakers make a price concession on bread over 1 day old.

THE "POLYS"

39. Since the issuance in 1943 of the tentative order proposing definitions and standards of identity for bread, it was discovered that the addition to bread dough of small amounts of certain substances, referred to as surface-active agents or emulsifying agents, causes the bread baked from such dough to be more compressible and to feel softer when squeezed. Soon after this discovery, certain products containing one or more such substances were offered for sale to bakers. (A somewhat similar effect obtained by using mono- and diglycerides is described in findings 5 and 6.) Three classes of compounds were involved. One class includes compounds prepared by reacting sorbitol with a fatty acid. In the reaction the sorbitol loses moisture and the resulting product is a fatty acid ester of sorbitan. Compounds of this class are distributed under the trade name of Spans. Products of a second class are prepared by reacting a sorbitan ester of a fatty acid with ethylene oxide. This reaction makes possible the addition to the sorbitan portion of the molecule of a predetermined number of ethylene-oxide groups. Compounds of this type prepared for use in food products theoretically contain from four to twenty such groups. They are distributed under the trade name of Tweens. A third class of compounds is prepared by reacting ethylene oxide directly with a fatty acid, or by first reacting ethylene oxide with water, forming a glycol, and then reacting this glycol with a fatty acid. There are a great number of compounds possible in each of these three classes, due to the possibility of using different fatty acids and different amounts of the ethylene oxide.

The classes of compounds known as Spans and Tweens were used in the baking industry in a limited way prior to the discovery that some surface-active agents made bread feel softer. Mixtures of Spans or Tweens or both with other substances were sold under trade names and represented for a time as useful to the baking industry as egg substitutes. As bakers became acquainted with the properties of the various special products offered them, a compound of stearic acid and ethylene oxide (or a glycol and stearic acid) containing about 40 percent stearic acid (chemical name polyoxyethylene monostearate; widely used trade names Myrj 45 and Sta-Soft) became the most generally used. It was distributed to the baking industry beginning early in 1947.

During the latter years of the Second World War practically all bakers reduced the proportion of shortening in bread. They began to return to prewar practices after orders of the War Food Administration regulating the use of the various ingredients of bread were rescinded. Shortening at this time was high in price, and there is reason to believe that some bakers were influenced in their decision to use a preparation containing a surface-active agent because of merchandising claims that its use would make possible a reduction in shortening without materially changing the properties of the finished bread.

Representations were made by a number of promoters of the use of polyoxyethylene monostearate that it retarded or prevented the staling of bread. Experience by bakers in the use of polyoxyethylene monostearate showed that 0.5 part to 100 parts of flour in bread dough made measurably softer bread, and that this effect was obtained even if no shortening was used. Experience further showed that breads in which polyoxyethylene monostearate was used remained slightly softer over a period of days than breads of the same composition except that they contained no polyoxyethylene monostearate. Thus bakers using polyoxyethylene monostearate were able to place on the market breads which appealed to the large

segment of consumers who choose bread because it feels soft upon squeezing the wrapped loaf. Some bakers using polyoxyethylene monostearate in their bread advertised softness as an index to the freshness of their bread. No bakers, by advertisements or label statements, advised consumers of their use of this chemical to influence the softness of the bread.

Softness and freshness are intimately connected in the minds of purchasers of bread. Undoubtedly a great many purchasers were led to believe by the feeling of softness of breads containing surface-active agents that such bread was not as old as it actually was.

Whether the addition of polyoxyethylene monostearate to bread dough caused the bread to retain the properties of fresh bread, other than softness, for a longer period of time than similar bread without this substance is highly controversial. There was some persuasive testimony that the only significant effect from the addition of polyoxyethylene monostearate was to make the bread softer at the time of baking, without any effect on the rate of hardening or staling thereafter. Findings as to the exact action of this substance in affecting the properties of bread cannot be made with certainty from the evidence.

GLYCOLS

40. There was evidence tending to show that some of the polyoxyethylene monostearates prepared for food use contained small amounts of poisonous glycols of low molecular weight, that is, ethylene glycol and diethylene glycol. Due to the type of chemical reaction involved in combining ethylene oxide with water, with fatty acids, or with sorbitan, it is probable that a number of esters of varying molecular weight, including esters of higher and lower molecular weight than planned, are always present. Some polyoxyethylene glycols of quite high molecular weight have been found to cause injury when fed to test animals, and it is possible that small quantities of such substances, as well as esters of quite low molecular weight, are present in some of the polyoxyethylene monostearates sold to bakers. The range in quantity of such deleterious substances that might be present was not shown but the maximum is probably quite small.

EXPERIMENTAL FEEDINGS

41. Experimental feedings to test animals of substances in each of the three classes described indicated that when used in the diet of these animals in amounts several times greater than might be expected in the human diet they had no noticeable effect on the animals. However, when the amounts in the animal diet were increased to 10 percent or more of the dry matter there was some evidence of adverse effects.

The mechanism by which the lower animal body and the human body eliminate these products has been the subject of study in both experimental animals and in human subjects. This scientific work indicates that polyoxyethylene monostearate is largely split into stearic acid and a glycol and that the fatty acid portion is utilized for food. The glycol portion, according to some experimenters, is largely absorbed and later eliminated unchanged in the urine. Other experimenters, however, were never able to trace the fate of all the glycol portion indicating the possibility of its oxidation in the body or the possibility of its conversion into unrecognized substances. In general, experimental feeding to test animals indicated that only small portions, if any, of compounds of Span and Tween type were utilized for food. These substances appear to be excreted, for the most part, in the feces.

Experiments with polyoxyethylene monostearate and one of the Tweens were made by giving these substances to human subjects, most of whom were in a hospital following operations on the stomach. In the amounts given, there was no indication of injury to these patients, and some indication of increased fat absorption. One of these substances of the Tween class has been used to a limited extent by physicians, with no apparent injury, in attempting to promote the absorption of fat in patients suffering from faulty fat absorption. Experimental feeding of a solution containing Spans and Tweens to a group of college students showed no apparent injury, but control over the subjects was such that not much reliance can be placed on the results reported.

Reports were made of the examination of the urine of persons and of animals to detect the possible appearance of oxalic acid when compounds containing the polyoxyethylene group were fed to them. None of these experiments showed an increase in oxalic acid in the urine which could be ascribed definitely to the ingestion of the polyoxyethylene compounds. However, in some test animals fed large quantities of polyoxyethylene monostearate urinary calculi of undetermined composition were found.

There was testimony indicating the possibility that surface-active agents containing the polyoxyethylene group may influence the absorption in the human digestive tract of substances contained in fats, such as cholesterol, and possibly of other ingredients. This possibility, however, appears to be largely conjectural.

THE "POLYS," CONTINUED

42. Although the use of surface-active agents in bread may enable consumers to keep such bread longer before it becomes unpalatable, it is doubtful that any substantial number of consumers have benefited by the use in bread of the substances described in finding 39. Deception of some consumers as to the age of bread purchased has resulted from the use in it of polyoxyethylene monostearate. A slight lowering is indicated in the nutritive value of the bread in which compounds containing the polyoxyethylene group are used. The consequences of the use of chemicals having any significant potentiality for harm in any food consumed as extensively and continuously as bread are of great importance to public health. Although there has been no definite evidence of injury from the use of Spans, Tweens, or polyoxyethylene monostearate in amounts in which they are likely to occur in the diet from their use in bread, the investigational work does not definitely establish their safety, and the record does not permit a conclusion that bread containing them is safe for continuous use over the human life span. Apart from their possible toxicity, the record as a whole will not support a finding that it would promote honesty and fair dealing in the interest of consumers to recognize sorbitan esters of fatty acids, polyoxyethylene sorbitan esters of fatty acids, and polyoxyethylene esters of fatty acids as optional ingredients in breads, rolls and buns.

MOLD DEVELOPMENT

43. In addition to staling, bread is subject to spoilage from the growth of mold. If the surface of bread is moist it is a good medium for the growth of mold spores. The temperature of baking effectively destroys any mold spores in the dough, but such spores may be present in the bakery, and bread not suitably protected during and after cooling may become contaminated with such spores. When bread is sliced

and wrapped, as is the common practice among large bakeries, the moisture remaining in the bread is held inside the wrapper, keeping the surface of bread moist and so creating a favorable environment for the growth of mold spores which may have accumulated on the surface of the loaf or on the slices prior to wrapping. Unwrapped bread from which moisture can evaporate readily is less likely to become moldy. Mold development on bread is most rapid in warm weather, especially when the humidity is high.

44. The time necessary for the development of visible mold varies greatly, depending on a number of conditions. Under conditions most favorable to mold growth, a visible speck of mold may develop within 1 or 2 days after exposure of the bread to the spores. Under normal summer conditions, however, several days will elapse between the time of contamination and the appearance of a mold spot sufficiently large to be noticed.

MOLD INHIBITORS

45. A considerable number of bakers take no steps to protect their bread from mold other than controls within the bakery which tend to prevent contamination of the bread with mold spores. A few bakers have installed special precautionary devices for this purpose that are elaborate and beyond the means of bakers generally. Methods available to most bakers do not wholly prevent contamination, and where this occurs in sufficient degree and conditions are favorable to mold growth losses of bread may follow. Many bakeries, and probably a majority of wholesale bakeries, have adopted the practice of adding to the dough, at least during summer months, some substance that will retard the growth of mold on the bread. Proposals were made to recognize as optional ingredients for this purpose sodium and calcium propionates and sodium diacetate.

ROPY BREAD

46. In addition to spoilage from mold, decomposition and spoilage in bread are caused on rare occasions by the growth inside the loaf of a type of bacterium which, in spore form, can survive the temperature of baking. This bacterium Bacillus mesentericus, causes spoilage which in advanced stages is characterized by an unpleasant odor and a pasty consistency of the center of the loaf. This pasty material will pull out into fine threads, and such bread is said to be "ropy." B. mesentericus is known as the rope-forming organism.

SOURCE OF ROPE

47. Technical experts in the baking industry are not entirely in agreement as to how the rope organism enters bread dough, but they generally agree that the most probable means is through use in preparing the dough of raw materials contaminated with numerous spores of the organism. There is some possibility that spores may be air-borne and enter the dough from the air circulating in the bakery. In order for spoilage from rope organisms to develop in bread there must be a combination of circumstances where a considerable number of spores enter the dough and where the bread is held for some time after baking at a high temperature under conditions whereby the moisture in the bread is retained. Where such a combination of circumstances is present, large losses may occur from such spoilage.

ROPE PREVENTATIVES

48. A considerable number of bakers take no steps for the protection of bread from rope other than to use ingredients sufficiently low in spore content. The ordinary baker, however, has no means of quickly testing ingredients to determine if they are contaminated with rope-forming organisms and must rely upon suppliers to furnish ingredients that are safe to use. Much progress has been made by suppliers in safeguarding their products. Many bakers, however, probably including a majority of wholesale bakers, at some time during the year add some type of ingredient to dough as additional assurance against rope development.

49. It was found several years ago that materials that render the dough slightly more acid than normal are effective in preventing the development of the rope organism. The acidity of the finished bread need not be greater than pH 5.0. The necessary increase in acidity is frequently effected by adding about a pint of 100-grain vinegar for each 100 pounds of flour used in the dough. Another product used by bakers for increasing acidity is monocalcium phosphate, which is the acidifying ingredient in phosphated flour. About ½ pound or less of monocalcium phosphate for each 100 pounds of flour usually increases acidity sufficiently for this purpose, or phophated flour may be used. Other acids that are said not to interfere with yeast growth have also been tried to a limited extent. Lactic acid, in a quantity sufficient to reduce the pH of the bread to not less than 4.5 has recently been found to be a suitable acidifying ingredient of the dough for the purpose of preventing or retarding the growth of certain spore-forming organisms, the spores of which are not destroyed in the baking process. Sodium and calcium propionates have been found to be effective in retarding the growth of rope organism without a significant change in acidity. Sodium diacetate, which liberates acetic acid in the dough, has been used in lieu of vinegar and monocalcium phosphate against the possibility of spoilage due to rope.

50. The quantity of calcium propionate or sodium propionate or both used in white bread for the purposes indicated in findings 45 and 49 need not exceed 0.32 part by weight for each 100 parts by weight of flour used. The quantity of sodium diacetate used for such purposes need not exceed 0.4 part by weight. The quantity of any vinegar used for the purposes indicated in finding 49 need not exceed 1 pint of any vinegar of 100-grain strength for each 100 pounds of flour used, or corresponding amounts of vinegar of less strength to furnish an equivalent amount of acetic acid. The quantity of monocalcium phosphate used for the purposes indicated in finding 49 exceeds the amount used as a yeast food (for which purpose the maximum amount used is 0.25 part for each 100 parts by weight of flour used) but does not exceed 0.75 part for each 100 parts by weight of flour.

51. The evidence shows that a substantial proportion of bakers do not consider that they have a mold or rope problem and that they use none of the substances referred to in finding 49. Most bakers consider that they do have a mold or rope problem during the months of relatively high temperature, particularly when the humidity is high, and these bakers use such substances during those months. Some bakers consider that they have a mold and rope problem throughout the entire year and use such substances continuously. The evidence points to the possibility that the use of such substances may result in practices contrary to consumer interest, but does not establish that such practices exist or are likely to develop to any material extent.

52. All the substances used as set forth in findings 49 and 50 act as preservatives in bread and rolls in that they delay spoilage by certain micro-organisms. All such substances, except vinegar, are chemicals within the usual meaning of the term.

MILK BREAD & ROLLS

53. The foods commonly and usually known as milk bread and milk rolls or milk buns differ from bread and rolls primarily in that they contain a certain minimum of milk solids. Findings 2 to 7 and 14 to 53, inclusive, are applicable to milk bread and milk rolls.

MILK PRODUCTS USED

54. Milk bread is prepared in the home, and to a considerable extent in commercial bakeries, by using milk as the sole ingredient for moistening the flour and other ingredients to make the dough. However, many bakers use, instead of milk, various milk products (with or without water), containing essentially the same quantity of milk solids as would be supplied by milk when it is used as the sole wetting agent. Milk products used for this purpose, and which are suitable for such use, are concentrated milk, evaporated milk, sweetened condensed milk, dried milk, and reconstituted milk (see finding 56).

MILK FAT

55. The solids of milk may be divided into two well-recognized components, milk fat and nonfat milk solids. The relative proportion of fat and nonfat milk solids varies somewhat, but in milk of average composition as delivered to consumers the quantity of nonfat milk solids is not more than 2.3 times the quantity of milk fat. In milks of greater richness than average milk the fat content may rise to a point where the nonfat milk solids is about 1.2 times the milk fat.

RECONSTITUTION OF MILK

56. The ingredients used to supply milk-constituent solids in the reconstitution of milk for making milk bread are skim milk, concentrated skim milk, evaporated skim milk, sweetened condensed skim milk, sweetened condensed partly skimmed milk, and nonfat dry milk solids or any two or more of these, combined with butter or cream or both. Unless a maximum limit is set on the proportion of nonfat dry milk solids to milk fat in reconstituting milk, abuses can easily arise through the use of decreasing quantities of milk fat and increasing quantities of the less expensive nonfat milk solids. It is reasonable to require that when reconstituted milk is used the proportion of nonfat milk solids to milk fat fall within the range set forth in finding 55.

USE OF FLUID MILK

57. The quantity of water necessary to make flour into dough varies somewhat, but it is generally about 60 pounds to each 100 pounds of flour, and in practically no case is less than 58 pounds to 100 pounds of flour. In milk of average composition, 58 pounds of moisture is associated with 8.23 pounds of milk solids. A reasonable minimum requirement for milk solids in milk bread made with dairy ingredients other than fluid milk is 8.2 pounds to each 100 pounds of flour. Because of variation in the total solids content of fluid milk and because of differences in the quantity of moisture absorbed in making the dough, it would not be reasonable to prescribe a minimum based on the average composition of milk for the milk solids content of milk bread when fluid milk is used as the sole moistening ingredient.

BUTTERMILK IN MILK BREAD

58. Milk bread is generally considered by consumers to be made from milk and not from buttermilk. Buttermilk and its products, such as those listed in finding 13, are not appropriate ingredients of milk bread.

SPECIAL BREADS

59. In the announcement of the hearing definitions and standards of identity were proposed for:

Cream bread and cream rolls or cream buns.
Butter bread and butter rolls or butter buns.
Egg bread and egg rolls or egg buns.
Butter and egg bread and butter and egg rolls or butter and egg buns.
Honey bread and honey rolls or honey buns.
Milk and honey bread and milk and honey rolls or milk and honey buns.

In each instance the American Bakers Association proposed other definitions and standards differing from the proposals for hearing chiefly in that they would require substantially lesser amounts of the ingredients indicated by the names of the various kinds of bread and rolls or buns.

ABA PROPOSALS

60. The quantities of the characterizing ingredients specified in the published proposal and the quantities recommended by the American Bakers Association are shown in the following tabulation ("parts" signify parts by weight for each 100 parts by weight of flour used in preparing dough):

	Published Proposals	Proposals by American Bakers Association
Cream bread Cream rolls Cream buns	12 parts of milk fat from cream or combination of milk and nonfat milk solids in certain specified proportions.	4 parts of milk fat.
Butter bread Butter rolls Butter buns	12 parts of milk fat from butter	Do.
Egg bread Egg rolls Egg buns	5 parts of egg solids	2 parts of egg solids.
Butter and egg bread Butter and egg rolls Butter and egg buns	12 parts of milk fat from butter, 5 parts egg solids	4 parts of milk fat, 2 parts of egg solids.
Honey bread Honey rolls Honey buns	16 parts of honey solids	4 parts of honey solids.*
Milk and honey bread Milk and honey rolls Milk and honey buns	Milk content same as for milk bread, 16 parts honey solids	Milk content same as for milk bread, 4 parts of honey solids.

* Three parts of honey solids was recommended by a witness introduced by the American Bakers Association.

POSSIBLE DECEPTION

61. There have been sold at times under the names of the products listed in finding 60, or under similar names, breads containing little or none of the ingredients for which the breads have been named. This practice has not been widespread. The amount of such bread is small in comparison with the total amount of bread sold, but this practice has tended to mislead the consumer, giving the impression that these ingredients are used in such substantial amounts as to characterize the breads.

DIFFERENCE NOT APPARENT

62. The evidence does not establish that products containing these ingredients in the quantities proposed by the American Bakers Association (see finding 60) are distinguishable by the ordinary consumer from the product commonly known as bread or white bread. It is not shown that benefit to consumers would result from the promulgation of definitions and standards of identity for these products as proposed by the American Bakers Association.

NO SPECIAL BREAD STANDARDS

63. There is not shown to be, nor is there likely to develop, a demand on the part of consumers for bread or rolls containing the quantities of these ingredients in the published proposals that were supported by the Food and Drug Administration (see finding 60). The evidence does not establish that such proposed definitions and standards of identity would be reasonable.

RAISIN BREAD & ROLLS

64. The foods commonly and usually known as raisin bread and raisin rolls or raisin buns differ from bread and rolls primarily in that raisins are added to the dough before baking. Seedless (or seeded) raisins are suitable for such use. They are usually washed and are often soaked in water before being added to the dough. Except as noted in findings 66 and 67, findings 2 to 52, inclusive (except finding 9), are applicable to raisin bread and raisin rolls.

AMOUNT OF RAISINS USED

65. The quantity of raisins used in making raisin bread varies somewhat. A minimum requirement for raisins based on the weight of the raisins in the loaf was contained in the advisory standard for raisin bread promulgated some years ago. A more understandable requirement from the standpoint of the baker is a specification of the weight of raisins (before soaking or washing) used with each 100 parts by weight of flour. The requirement of the advisory standard calculated to this basis is about 35 parts of raisins to each 100 parts of flour. In recent years it has become the practice of most bakers to use substantially more raisins, and a minimum requirement of 50 parts of raisins to each 100 parts of flour now conforms more nearly to consumer preference and good bakery practice.

RAISIN SIRUP

66. When making raisin bread some bakers use as a saccharine ingredient a raisin sirup made by concentrating a water extract of raisins (referred to in finding 16).

Such an extract is suitable for use in raisin bread, but such raisin extractives as are incorporated in this manner do not take the place of raisins used in making the raisin bread. Raisin bread and raisin rolls are sometimes prepared with an icing or frosting.

TOTAL SOLIDS AND RAISIN BREAD

67. The method of determining total solids, described in finding 4, must be modified slightly to be applicable to raisin bread and raisin rolls, in order to insure the proper mixing of raisins in the sample. This can be accomplished by passing the sample twice through a food chopper and then taking a portion for solids determination without attempting to pass the ground sample through a 20-mesh sieve.

WHOLE WHEAT BREAD

68. The foods commonly and usually known as whole wheat bread, graham bread, entire wheat bread, and whole wheat rolls, graham rolls, wheat rolls, or whole wheat buns, graham buns, and entire wheat buns differ from white bread and white rolls only in that the dough is made with whole wheat flour or bromated whole wheat flour, and no flour, bromated flour, or phosphated flour is used therein. Findings 2 to 52, inclusive (except finding 9), are applicable to whole wheat bread and whole wheat rolls, except that the maximum limit for propionates (see finding 50) is 0.38 part by weight to each 100 parts by weight of whole wheat flour used.

CRACKED WHEAT BREAD

69. Several different kinds of bread and rolls are prepared which differ from white bread and white rolls only in that the dough is made by using various mixtures of two or more of the wheat ingredients flour (including bromated flour and phosphated flour), whole wheat flour, cracked wheat, and crushed wheat. In order to obtain in finished bread and rolls of these kinds the characteristics of each of the wheat ingredients used, it is necessary that the quantity of each such ingredient be not less than 20 percent by weight of the mixture of wheat ingredients used. Findings 2 to 52, inclusive (except finding 9), are applicable to bread and rolls of these kinds, except that the maximum limit for propionates (see finding 50) is 0.38 part by weight for each 100 parts by weight of the mixture of wheat ingredients.

LABELING REQUIREMENTS

70. Bread and rolls of these kinds are ordinarily labeled with the word "bread" or "rolls," preceded by the name of one of the wheat ingredients (for example, "cracked wheat bread"). Consumers are confused as to the composition of such products by the failure to disclose in the name other wheat ingredients present in characterizing quantities. Names for them which are accurate and informative are the words "bread," "rolls," and "buns," as the case may be, preceded by words which show the wheat ingredients used, in the order of their predominance, if any, by weight in the mixture (for example, "white and whole wheat bread").

ENRICHED BREAD & ROLLS

71. "Enriched bread" and "enriched rolls" or "enriched buns" are the common and usual names of baked products identical with bread and rolls, respectively, ex-

cept that they contain added nutrients and are not subject to the limitations indicated in finding 9. The reasons for enriching flour and for regulating such enrichment are applicable to enriched bread and enriched rolls; such reasons are set forth in findings 33 to 41, inclusive, of the order prescribing a definition and standard of identity for enriched flour (6. F. R. 2574), as modified and supplemented by findings 1 to 11, inclusive, of the order amending that definition and standard of identity (8. F. R. 9115). The basis for requiring or permitting the particular enriching ingredients and the particular quantities thereof specified in such findings is also applicable to enriched bread and enriched rolls. Findings 2 to 52, inclusive (except findings 9 and 30), are applicable to enriched bread and enriched rolls.

AMOUNT OF VITAMINS

72. The quantities of vitamins and minerals in enriched bread and enriched rolls are those which result from the use of enriched flour or enriched bromated flour in lieu of flour, bromated flour, or phosphated flour. These quantities may be contributed by any of the following methods, or by any two or more of them in combination:

1. Enriched flour or enriched bromated flour is used, in whole or in part.
2. The substances used for enriching flour (including wheat germ or partly defatted wheat germ in a quantity not more than 5 parts by weight to each 100 parts of flour, bromated flour, and phosphated flour used) are added in making the dough, under the conditions permitted by 21 CFR 15.10, for the addition of such substances in preparing enriched flour.
3. Ingredients of bread which contain such vitamins or minerals (e. g., yeast, dried skim milk, monocalcium phosphate) are used within the limits, if any, for such use in bread.

USE OF ENRICHED FLOUR

73. It would not be reasonable to subject enriched bread or enriched rolls to any requirement for or limitation on enrichment that cannot be met in ordinary commercial practice by the use of any enriched flour which conforms to the definition and standard of identity prescribed in 21 CFR 15.10.

MAXIMA AND MINIMA

74. The flour content of enriched bread and enriched rolls varies from a minimum of about 60 percent to a maximum of about 75 percent, depending upon such factors as the quantity of ingredients other than flour used and the moisture content of the finished products. In baking such products there is some loss of vitamins, mostly through destruction in the crust. Such losses of niacin, riboflavin, and vitamin D are negligible, and in the cases of niacin and riboflavin are compensated by some contribution of these vitamins by yeast and other ingredients commonly used. Except as noted for thiamine, riboflavin, and calcium in findings 75, 76, and 77, minima for the vitamins and minerals in enriched bread and enriched rolls of 60 percent of the minima prescribed for enriched flour, and maxima of 75 percent of the maxima for enriched flour, are, when rounded off to the nearest significant decimal point, reasonable limits when enriched flour is used to make enriched bread and enriched rolls. On this basis each pound of enriched bread or enriched rolls contains not less than 10 milligrams nor more than 15 milligrams of niacin; not less than 8

milligrams nor more than 12.5 milligrams of iron; and when the optional ingredient vitamin D is used, not less than 150 U.S.P. units nor more than 750 U.S.P. units of such vitamin. It would not be reasonable to prescribe minima and maxima for vitamins and minerals, when they are added in making the dough, different from the minima and maxima prescribed when enriched flour is used. An unnecessarily wide spread between the minima and maxima would likely lead to competitive increases between manufacturers, accompanied by such advertising claims as would confuse consumers as to their nutritionary needs and the value of enriched bread in supplying those needs. Consumer understanding of the value of enriched bread will be promoted by requiring its composition to be as nearly uniform as practicable as to both quantities and kinds of nutritive factors present.

VITAMIN LOSSES

75. In baking enriched bread and enriched rolls losses of thiamine are appreciable. However, if flour enriched to the minimum of 2 milligrams of thiamine per pound is used there is sufficient contribution of thiamine from the yeast and other ingredients customarily added that in common commercial practice the finished products contain not less than 1.1 milligrams of thiamine per pound. If flour enriched to the maximum of 2.5 milligrams per pound is used, the thiamine content of the finished products, after due allowances are made for contributions from such ingredients and for baking losses, will not exceed 1.8 milligrams per pound.

VITAMINS FROM YEAST AND MILK

76. Yeast and milk or its products used in making enriched bread and rolls may contribute as much as 0.48 milligram of riboflavin per pound of bread or rolls. When these are used with enriched flour containing 1.5 milligrams of riboflavin per pound, the riboflavin content of the enriched bread or enriched rolls may approach 1.6 milligrams per pound. When milk and its products are not used, and the enriched flour contains the minimum 1.2 milligrams of riboflavin per pound, the riboflavin content of the enriched bread or enriched rolls may fall to nearly 0.7 milligram per pound.

SOURCES OF CALCIUM

77. Nonfat dry milk solids, so-called bread improvers, rope inhibitors, and other optional ingredients used in making bread and rolls may contribute nearly 300 milligrams of calcium per pound to bread or rolls. When these are used with enriched flour containing 625 milligrams of calcium per pound, the calcium content of the enriched bread or enriched rolls may approach 800 milligrams per pound, particularly if water used in making the dough is high in calcium. When these are not used and the enriched flour contains the minimum of 500 milligrams of calcium per pound the calcium content of the enriched bread or enriched rolls may fall to about 300 milligrams per pound.

LIMITS FOR VITAMINS AND MINERALS

78. The following are reasonable limits for the specified vitamins and minerals in enriched bread, enriched rolls or enriched buns:

	Minimum	Maximum
Required ingredients:		
Thiamine	1.10 mg. per lb.	1.8 mg. per lb.
Niacin	10.0 mg. per lb.	15.0 mg. per lb.
Riboflavin	0.7 mg. per lb.	1.6 mg. per lb.
Iron	8.0 mg. per lb.	12.5 mg. per lb.
Optional ingredients:		
Calcium	300 mg. per lb.	800 mg. per lb.
Vitamin D	150 U.S.P. units per lb.	750 U.S.P. units per lb.

LABEL DECLARATIONS

79. Several proposals were made to require label declarations of certain optional ingredients used in bread. There was testimony indicating that some ingredients of bread are causes of allergic manifestations, and that consumers who are sensitive to such ingredients might be benefited by label declaration of these ingredients. There was conflicting testimony as to the prevalence of food allergies and the extent to which the ingredients of bread are the causative agents. The evidence does not indicate that a significant proportion of consumers are sensitive to any particular optional ingredient whose presence in bread would not be expected without label declaration, or would benefit by label declarations of any or all of the optional ingredients used in bread.

A witness representing the Union of Orthodox Jewish Congregations of America, Inc., recommended that the origin and type of shortening used in bread be stated on the label, so that those persons who wished to observe the Jewish dietary laws might avoid the purchase of bread containing "non-kosher" fat. It was not shown that a significant number of persons observing the Jewish dietary laws would be benefited by such a label declaration.

A witness appearing on behalf of the American Home Economics Association recommended that bread be labeled to show all the ingredients used in excess of 1 percent of the weight of the flour, the number of calories in a specified unit of weight, the percentage of protein in the loaf, and the maximum percentage of water in the loaf. Interest in such labeling, except in the case of bread and rolls represented for or purporting to be for special dietary use, is restricted to small groups. Requirements for informative labeling of foods for special dietary uses are contained in regulations adopted under authority of section 403 (j) of the Federal Food, Drug, and Cosmetic Act (21 U. S. C. 343 [j]).

Conclusions. Upon consideration of the whole record and the foregoing findings of fact, it is concluded that the adoption of the following definitions and standards of identity for various kinds of breads and rolls or buns will promote honesty and fair dealing in the interest of consumers.

THE PROPOSED STANDARDS FOR BREAD AND ROLLS

§ 17.1 *Bread, white bread, and rolls, white rolls, or buns, white buns; identity; label statement of optional ingredients.* (a) Each of the foods bread, white bread, rolls, white rolls, buns, white buns is prepared by baking a kneaded yeast-leavened dough, made by moistening flour with water or with one or more of the optional

liquid ingredients specified in this section or with any mixture of water and one or more of such ingredients. The term "flour," unqualified, as used in this section, includes flour, bromated flour, and phosphated flour. The potassium bromate in any bromated flour used and the monocalcium phosphate in any phosphated flour used shall be deemed to be optional ingredients in the bread or rolls. Each of such foods is seasoned with salt, and in its preparation one or more of the optional ingredients prescribed by subparagraphs (1) to (14), inclusive, of this paragraph may be used:

(1) Shortening, which may contain lecithin and which may contain not more than 25 percent by weight of mono- and diglycerides of fat-forming fatty acids.

(2) Milk, concentrated milk, evaporated milk, sweetened condensed milk, dried milk, skim milk, concentrated skim milk, evaporated skim milk, sweetened condensed partly skimmed milk, sweetened condensed skim milk, nonfat dry milk solids, or any combination of two or more of these; except that any such ingredient or combination, together with any butter and cream used, is so limited in quantity or composition as not to meet the requirements for milk or dairy ingredients prescribed for milk by § 17.3.

(3) Buttermilk, concentrated buttermilk, dried buttermilk, sweet cream buttermilk, concentrated sweet cream buttermilk, cheese whey, concentrated cheese whey, dried sweet cream buttermilk, dried cheese whey, milk proteins, or any combination of two or more of these.

(4) Liquid eggs, frozen eggs, dried eggs, egg yolks, frozen egg yolks, dried yolks, egg white, frozen egg white, dried egg white, or any combination of two or more of these.

(5) Sugar, invert sugar (in congealed or sirup form), light-colored brown sugar, refiner's sirup, dextrose, honey, corn sirup, glucose sirup, dried corn sirup, dried glucose sirup, nondiastatic malt sirup, nondiastatic dried malt sirup, molasses (except blackstrap molasses), or any combination of two or more of these.

(6) Malt sirup, dried malt sirup, malted barley flour, malted wheat flour, each of which is diastatically active; harmless preparations of enzymes obtained from Aspergillus oryzae; or any combination of two or more of these.

(7) Inactive dried yeast of the genus Saccharomyces cerevisiae; but the total quantity thereof is not more than 2 parts for each 100 parts by weight of flour used.

(8) Harmless lactic-acid producing bacteria.

(9) Corn flour (including finely ground corn meal), potato flour, rice flour, wheat starch, cornstarch, milo starch, potato starch, sweet potato starch (any of which may be wholly or in part dextrinized), dextrinized wheat flour, soy flour, or any combination of two or more of these; but the total quantity thereof is not more than 3 parts for each 100 parts by weight of flour used.

(10) Ground dehulled soybeans, which may be heat-treated and from which oil may be removed, but which retain enzymatic activity; but the quantity thereof is not more than 0.5 part for each 100 parts by weight of flour used.

(11) Calcium sulfate, calcium lactate, calcium carbonate, ammonium phosphates, ammonium sulfate, ammonium chloride, monocalcium phosphate, dicalcium phosphate, or any combination of two or more of these; but the total quantity of such ingredients (not including the monocalcium phosphate in any phosphated flour used) is not more than 0.25 part for each 100 parts by weight of flour used.

(12) Potassium bromate, potassium iodate, calcium peroxide, or any combination of two or more of these; but the total quantity thereof (including the potassium bromate in any bromated flour used) is not more than 0.0075 part for each 100 parts by weight of flour used.

(13) (i) Monocalcium phosphate, but the total quantity thereof, including the quantity in any phosphated flour used and any quantity added as permitted by subparagraph (12) of this paragraph, is more than 0.25 part but not more than 0.75 part by weight for each 100 parts by weight of flour used; or

(ii) A vinegar, in a quantity equivalent in acid strength to not more than 1 pint of 100-grain distilled vinegar for each 100 pounds of flour used; or

(iii) Calcium propionate, sodium propionate, or any mixture of these, but the total quantity thereof is not more than 0.32 part for each 100 parts by weight of flour used; or

(iv) Sodium diacetate, but the quantity thereof is not more than 0.4 part for each 100 parts by weight of flour used; or

(v) Lactic acid, in such quantity that the pH of the finished bread is not less than 4.5.

(14) Spice, with which may be included spice oil and spice extract.

Each of such foods contains not less than 62 percent of total solids, as determined by the method prescribed in "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists," Sixth Edition 1945, page 260, section 20.84 (a), "Total Solids in Entire Loaf of Bread * * * Official," except that if the baked unit weighs 1 pound or more one entire unit is used for the determination, and if the baked unit weighs less than 1 pound, such number of entire units as weigh 1 pound or more is used for the determination.

(b) Bread, white bread is baked in units each of which weighs one-half pound or more after cooling. Rolls, white rolls, and buns, white buns are baked in units each of which weighs less than one-half pound after cooling.

(c) (1) When any optional ingredient, except a vinegar, permitted by paragraph (a) (13) of this section is used, the label shall bear the statement "........ added to retard spoilage," the blank being filled in with the name by which the ingredient used is designated in such paragraph.

(2) When an optional ingredient permitted by paragraph (a) (14) of this section is used, the label shall bear the statement "spiced" or "spice added" or "with added spice"; but in lieu of the word "spice" in such statements, the common or usual name of the spice may be used.

(3) Wherever the name of the food appears on the label so conspicuously as to be easily seen under customary conditions of purchase, the words and statements specified in this paragraph shall immediately and conspicuously precede or follow such name, without intervening written, printed, or graphic matter.

ENRICHED BREAD AND ROLLS

§ 17.2 *Enriched bread and enriched rolls or enriched buns; identity; label statement of optional ingredients.* (a) Each of the foods enriched bread, enriched rolls, enriched buns conforms to the definition and standard of identity, and is subject to the requirement for label statement of optional ingredients, prescribed for bread by § 17.1 (a) and (c), except that:

(1) Each such food contains in each pound not less than 1.1 milligrams and not more than 1.8 milligrams of thiamine, not less than 0.7 milligram and not more than 1.6 milligrams of riboflavin, not less than 10.0 milligrams and not more than 15.0 milligrams of niacin or niacinamide, and not less than 8.0 milligrams and not more than 12.5 milligrams of iron (Fe).

(2) Each such food may also contain as an optional ingredient added vitamin D in such quantity that each pound of the finished food contains not less than 150 U. S. P. units and not more than 750 U. S. P. units of vitamin D.

(3) Each such food may also contain as an optional ingredient added harmless calcium salts in such quantity that each pound of the finished food contains not less than 300 milligrams and not more than 800 milligrams of calcium (Ca).

(4) Each such food may also contain as an optional ingredient wheat germ or partly defatted wheat germ; but the total quantity thereof, including any wheat germ or partly defatted wheat germ in any enriched flour used, is not more than 5 percent of the flour ingredient.

(5) Enriched flour may be used, in whole or in part, instead of flour.

(6) The limitation prescribed by § 17.1 (a) (2) on the quantity and composition of milk and dairy ingredients does not apply.

As used in this section, the term "flour," unqualified, includes bromated flour and phosphated flour; the term "enriched flour" includes enriched bromated flour. The prescribed quantity of any substance referred to in subparagraphs (1), (2), and (3) of this paragraph may be supplied, or partly supplied, through the use of enriched flour; through the direct addition of such substance under the conditions permitted by § 15.10 of this chapter for supplying such substance in the preparation of enriched flour; through the use of any ingredient containing such substance, which ingredient is required or permitted by § 17.1 (a) within the limits, if any, prescribed by such section, as modified by subparagraph (6) of this paragraph; through the use of wheat germ; or through any two or more of such methods.

(b) Enriched bread is baked in units each of which weighs one-half pound or more after cooling. Enriched rolls or enriched buns are baked in units each of which weighs less than one-half pound after cooling.

MILK BREAD AND ROLLS

§ 17.3 *Milk bread and milk rolls or milk buns; identity; label statement of optional ingredients.* (a) Each of the foods milk bread, milk rolls, milk buns conforms to the definition and standard of identity, and is subject to the requirements for label statement of optional ingredients, prescribed for bread and rolls or buns by § 17.1 (a) and (c), except that:

(1) Milk is used as the sole moistening ingredient in preparing the dough; or in lieu of milk one or more of the dairy ingredients prescribed in paragraph (c) of this section is used, with or without water, in a quantity containing not less than 8.2 parts by weight of milk solids for each 100 parts by weight of flour used (including any bromated flour or phosphated flour used).

(2) No ingredient permitted by § 17.1 (a) (3) is used.

(b) Milk bread is baked in units each of which weighs one-half pound or more after cooling. Milk rolls or milk buns are baked in units each of which weighs less than one-half pound after cooling.

(c) The dairy ingredients referred to in paragraph (a) (1) of this section are concentrated milk, evaporated milk, sweetened condensed milk, dried milk, and a mixture of butter or cream or both with skim milk, concentrated skim milk, evaporated skim milk, sweetened condensed milk, sweetened condensed partly skimmed milk, nonfat dry milk solids, or any two or more of these, in such proportion that the weight of nonfat milk solids in such mixture is not more than 2.3 times and not less than 1.2 times the weight of the milk fat therein.

RAISIN BREAD AND ROLLS

§ 17.4 *Raisin bread and raisin rolls or raisin buns; identity; label statement of optional ingredients.* (a) Each of the foods raisin bread, raisin rolls, raisin buns conforms to the definition and standard of identity, and is subject to the requirements for label statement of optional ingredients, prescribed for bread and rolls or buns by § 17.1 (a) and (c), except that:

(1) Not less than 50 parts by weight of seeded or seedless raisins are used for each 100 parts by weight of flour used (including any bromated flour or phosphated flour used).

(2) Water extract of raisins may be used, but not to replace raisins.

(3) The baked units may bear icing or frosting.

(4) The limitation prescribed by § 17.1 (a) (2) on the quantity and composition of dairy ingredients does not apply.

(5) In determining its total solids, instead of following the direction "Grind sample just to pass a 20-mesh sieve" (Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, Sixth Edition, 1945, page 260, section 20.84 (a), under "Total Solids in Entire Loaf of Bread * * * Official"), comminute the sample by passing it twice through a food chopper.

(b) Raisin bread is baked in units each of which weighs one-half pound or more after cooling. Raisin rolls or raisin buns are baked in units each of which weighs less than one-half pound after cooling.

WHOLE WHEAT BREAD AND ROLLS

§ 17.5 *Whole wheat bread, graham bread, entire wheat bread, and whole wheat rolls, graham rolls, entire wheat rolls, or whole wheat buns, graham buns, entire wheat buns; identity; label statement of optional ingredients.* (a) Each of the foods whole wheat bread, graham bread, entire wheat bread, whole wheat rolls, graham rolls, entire wheat rolls, whole wheat buns, graham buns, entire wheat buns conforms to the definition and standard of identity and is subject to the requirements for label statement of optional ingredients, prescribed for bread, rolls, and buns by § 17.1 (a) and (c), except that:

(1) The dough is made with whole wheat flour, and no flour is used therein.

(2) The limitation prescribed by § 17.1 (a) (2) on the quantity and composition of dairy ingredients does not apply.

(3) The total weight of calcium propionate, sodium propionate, or mixtures of these used is not more than 0.38 part for each 100 parts by weight of the whole wheat flour used.

As used in this section, the term "flour," unqualified, includes flour, enriched flour, bromated flour, enriched bromated flour, and phosphated flour; the term "whole wheat flour" includes whole wheat flour and bromated whole wheat flour. The potassium bromate in any bromated whole wheat flour used shall be deemed to be an optional ingredient in the whole wheat bread or whole wheat rolls.

(b) Whole wheat bread, graham bread, or entire wheat bread is baked in units each of which weighs one-half pound or more after cooling. Whole wheat rolls, graham rolls, entire wheat rolls, whole wheat buns, graham buns, or entire wheat buns are baked in units each of which weighs less than one-half pound after cooling.

CRACKED WHEAT, ETC.

§ 17.6 *Breads and rolls or buns made with combinations of flour, whole wheat flour, cracked wheat, and crushed wheat; identity; label statement of optional ingredients.* (a) The foods for which definitions and standards of identity are prescribed by this section are the foods each of which conforms to the definition and standard of identity, and is subject to the requirements for label statement of optional ingredients, prescribed for bread and rolls by § 17.1 (a) and (c), except that:

(1) The bread, roll, or bun is made with a combination of two or more of the following wheat ingredients, in which the weight of each such ingredient used is not less than 20 percent of the weight of such combination:

(i) Flour (including bromated flour and phosphated flour).

(ii) Whole wheat flour (including bromated whole wheat flour).

(iii) Cracked wheat.

(iv) Crushed wheat.

(2) The limitation prescribed by § 17.1 (a) (2) on the quantity and composition of dairy ingredients does not apply.

(3) The total weight of calcium propionate, sodium propionate, or mixtures of these used is not more than 0.38 part for each 100 parts by weight of such mixture.

(b) The potassium bromate in any bromated flour or bromated whole wheat flour used, and the monocalcium phosphate in any phosphated flour used shall be deemed to be optional ingredients in the finished baked products.

(c) If such food is baked in units each of which weighs one-half pound or more after cooling, the name of such food is "________ bread"; if in units each of which weighs less than one-half pound after cooling, "________ rolls" or "________ buns," the blank being filled in each instance with the names of the wheat ingredients, in the order of predominance, if any, by weight of such ingredients in the combination used in making the bread, as for example, "white and whole wheat bread." For the purposes of this provision, the name of the wheat ingredient specified in paragraph (a) (1) (i) of this section is "white"; in paragraph (a) (1) (ii) is "whole wheat," "graham," or "entire wheat"; in paragraph (a) (1) (iii) is "cracked wheat"; and in paragraph (a) (1) (iv) is "crushed wheat."

UNSALTED BREAD AND ROLLS

§ 17.7 *Unsalted breads and rolls or buns; identity; label statement of optional ingredients.* (a) Unsalted breads and unsalted rolls or buns are the foods each of which conforms to the definition and standard of identity, and is subject to the requirements for label statement of optional ingredients, prescribed for kinds of breads and rolls or buns by §§ 17.1, 17.2, 17.3, 17.4, 17.5, and 17.6, except that no salt is used in their preparation.

(b) The name of each kind of unsalted bread and unsalted roll or bun is the word "unsalted," followed by the name of the kind of bread and roll or bun prescribed in the definition and standard of identity therefor.

Any interested person whose appearance was filed at the hearing may, within 30 days from the date of publication of this tentative order in the FEDERAL REGISTER, file with the Hearing Clerk, Federal Security Agency, Room 5109, Federal Security Building, Fourth Street and Independence Avenue SW., Washington, D. C., written exceptions thereto. Exceptions shall point out with particularity the alleged errors

in this tentative order and shall contain specific references to the pages of the transcript of the testimony or the exhibits on which such exceptions are based. Such exceptions may be accompanied by a memorandum or brief in support thereof. Exceptions and accompanying memoranda or briefs shall be submitted in quintuplicate.

Dated: July 31, 1950.

[SEAL] JOHN L. THURSTON,
Acting Administrator.

[F. R. Doc. 50-6921; Filed, Aug. 7, 1950; 8:45 A.M.]

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SUBJECT INDEX